George C. Marshall Space Flight Center
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MSFC EMI Test Facility (METF)

EMI/EMC Facility Operating Procedure For SL-E-0002 – Book 3 Volume 1

Baseline
November 10, 2004

MSFC Engineering Directorate

Instrument and Payload Systems Department
Electrical Design and Integration Division
Electromagnetic Environmental Effects (E3)
and Electrical Integration Branch
EI24

VERIFY THAT THIS IS THE LATEST VERSION BEFORE USE

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1. INTRODUCTION

1.1 Purpose.

This procedure establishes the requirements and test operations necessary to prepare and operate the MSFC EMI Test Facility (METF), and to perform SL-E-0002 Rev F Book 3 Volume 1 testing in support of EMI qualification and development testing as defined by the Customer Agreement Form (CAF), MSFC Form 4404, submitted by appropriate test requestors.

1.2 Responsibilities.

The operation of this facility and the performance of this facility operating procedure (FOP) shall be conducted or coordinated by the assigned personnel of the Marshall Space Flight Center, Engineering Directorate, Instrument and Payload System, Electrical Design and Integration Division, Electromagnetic Environmental Effects (E3) Team, EI24.

It shall be the responsibility of the customer test requestors to define EMI/EMC requirements and services desired and to submit these using MSFC Form 4404, EMI Test CAF. EI24 personnel are available to assist in determining the EMI/EMC requirements if requested.

1.3 Emission and susceptibility designations.

The emissions and susceptibility and associated test procedure requirements in this standard are designated in accordance with an alphanumeric coding system. Each requirement is identified by a two-letter combination followed by a three digit number. The number is for reference purposes only. The meaning of the individual letters is as follows:

C = Conducted
R = Radiated
E = Emission
S = Susceptibility
TT = Transient emission

a. Conducted emissions requirements are designated by "CE---."
b. Radiated emissions requirements are designated by "RE---."
c. Conducted susceptibility requirements are designated by "CS---."
d. Radiated susceptibility requirements are designated by "RS---."
e. Transient Test (TT) emissions requirements are designated by “TT---.”
f. "---" = numerical order of requirement from 101 to 199.

2. APPLICABLE DOCUMENTS

The following documents and reference documents of the date and issue shown form a part of this document to the extent specified herein.

2.1 Applicable Documents.

The following documents of the date and issue shown form a part of this document to the extent specified herein.

EI24-002 (Current Issue)	Organizational Issuance, EI24 Electromagnetic Environmental Effects (E3) Team, EMI/PQ Testing
SL-E-0002 Book 3 Volume 1 (Current Issue)	Space Shuttle Specification, Electromagnetic Interference Characteristics, Requirements for Equipment, Book 3, New or Modified Equipment.

2.2 Reference Documents.

The following documents are cited as reference documents.

ANSI C63.2	Standard for Instrumentation Electromagnetic Noise and Field Strength, 10kHz to 40GHz
ANSI C63.14	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9kHz to 40GHz
ANSI/NCSL Z540-1	General Requirements for Calibration Laboratories and Measuring and Test Equipment
ASTM E 380	Standard for Metric Practice (Department of Defense adopted)
IEEE C95.1-1991	IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300GHz
ISO10012-1	Quality Assurance Requirements for Measuring Equipment
MWI 8730.5	Control of Inspection, Measuring, and Test Equipment
SAE ARP 958	Electromagnetic Interference Measurement Antennas, Standard Calibration Requirements and Methods

2.3 Order of precedence.

In the event of a conflict between the text of this FOP and the references cited herein, the text of this FOP shall take precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 General.

The terms used in this standard are defined in ANSI C63.14. In addition, the following definitions are applicable for the purpose of this standard.

3.2 Acronyms used in this standard.

a. BIT - Built-in Test
b. EMC - Electromagnetic Compatibility
c. EME - Electromagnetic Environment
d. EMI - Electromagnetic Interference
e. EMICP - Electromagnetic Interference Control Procedures
f. EMITP - Electromagnetic Interference Test Procedures
g. EMITR - Electromagnetic Interference Test Report
h. ERP - Effective Radiated Power
i. EUT - Equipment Under Test
j. GFE - Government Furnished Equipment
k. ISM - Industrial, Scientific and Medical
l. LISN - Line Impedance Simulation Network
m. METF - MSFC EMI Test Facility
m. NDI - Non-Developmental Item
n. RF - Radio Frequency
o. RMS - Root Mean Square
p. SSV - Space Shuttle Vehicle
p. TEM - Transverse Electromagnetic
q. TPD - Terminal Protection Device

3.3 External installation.

An equipment location on the SSV which is exposed to the external electromagnetic environment, such as the payload bay when the doors are open, which does not use electrically conductive treatments on the canopy or windscreen.

3.4 Flight-line equipment.
Any support equipment that is attached to or used next to the SSV during pre-flight or post-flight operations, such as uploading or downloading data, maintenance diagnostics, or equipment functional testing.

3.5 Internal installation.
An equipment location on the SSV which is totally inside an electrically conductive structure, such as an avionics bay internal to the Orbiter.

3.6 Metric units.
Metric units are a system of basic measures which are defined by the International System of Units based on "Le System International d'Unites (SI)", of the International Bureau of Weights and Measures. These units are described in ASTM E 380.

3.7 Non-developmental item.
Non-developmental item is a broad, generic term that covers material available from a wide variety of sources both Industry and Government with little or no development effort required by the procuring activity.

3.8 Safety critical.
A category of subsystems and equipment whose degraded performance could result in loss of life or loss of vehicle or platform.

3.9 Test setup boundary.
The test setup boundary includes all enclosures of the Equipment Under Test (EUT) and the 2 meters of exposed interconnecting leads (except for leads which are shorter in the actual installation) and power leads required by 5.1.8.6.

4. SAFETY/QUALITY ASSURANCE INFORMATION

4.1 General safety requirements.

Each individual participating in METF Facility and EMI/EMC test operations is responsible for compliance with safety regulations.

Normal safety procedures for laboratory environments as identified in EI24-002 will be observed.

During radiated susceptibility test where high power levels of RF energy are being radiated through antennas to the equipment under test (EUT), it is mandatory that the doors of the shielded enclosure where the test is being conducted be closed and secured. This is a requirement to reduce to safe levels power densities that may exceed the maximum permissible exposure to personnel in the immediate area. Reference IEEE C95.1-1991 Standard for Safety Levels with Respect to Human Exposure to RF Electromagnetic Fields, 3kHz to 300GHz.

4.2 Safety critical/hazardous operations.

No safety critical or hazardous operations are associated with this procedure.

4.3 Personnel protective equipment (PPE).

Any requirements for PPE during EMI/EMC testing that is unique to the EUT shall be identified by the customer in the customer agreement process and shall be the responsibility of the customer.

4.4 Hardware handling.

Handling of EUTs designated for EMI/EMC testing shall be the responsibility of the customer as mutually agreed upon in the Customer Agreement process.

4.5 Cleanliness Requirements.

The METF can be maintained as an environmentally controlled test area to 300K clean room requirements. However, normal test operations do not require the 300K requirements. If 300K clean room requirements are required for a particular EUT, that requirement shall be coordinated as part of the customer agreement form.

4.4 Electrostatic Discharge Requirements.

If an EUT designated for EMI/EMC testing is identified as ESD sensitive, then it shall be the responsibility of the customer to identify all areas of ESD sensitivity, grounding requirements and special handling in the Customer Agreement process.

4.5 Grounding requirements.

The METF power distribution and grounding will be operated to the terms identified in the appropriate sections of the standards, specifications and requirements of EMI/EMC testing. Specific power supply grounding or ground isolation shall be identified by the test customer in the Customer Agreement process.

4.6 Electrical conventions.

The following color conventions will be used on test leads during the course of EMI/EMC testing and on EUT operations and setup.

Earth or structural ground	Green
DC common or return	Black or Green (if tied to earth or structural ground)
DC voltages above ground	Red
DC voltages below ground	Yellow

4.7 Emergency telephone numbers.

Fire	911
Ambulance	911
Security	4-4357 Option 1
Facilities	4-4357 Option 4

4.8 Emergency shutdown procedures.

In case of an emergency, perform the emergency shutdown procedures listed in Section 4.9.

In the event of severe weather during test operations, perform the emergency shutdown procedure and proceed immediately to the proper shelter area.

The EI24 safety monitor and alternate will make every effort to advise the METF and EUT operators of any planned fire drills. If properly notified, testing may continue during a planned fire drill. However, if the fire alarm sounds and it cannot be verified that a fire drill is taking place, perform the emergency shutdown procedure, then evacuate the METF and building 4708 to the designated EI24 marshalling area.

4.9 EMERGENCY PROCEDURES

The following operational conditions could constitute an emergency condition requiring immediate attention or power removal.

- EUT exceeds normal operational current limits.
- Electrical problems resulting in visible smoke, arcing, sparks, excessive heating, unusual sounds etc. with the EUT or with METF equipment

4.9.1 Power removal.

- Open EUT power supply circuit breakers.
- Turn off all EUT power supplies
- Turn off EUT Ground Support Equipment (GSE)
- Turn off METF test equipment
- In the event that an unexpected and complete METF shutdown is required, hit any of the red Emergency Power Off (EPO) switches located in the shielded enclosure test areas as shown in Figure 1. This will shut down all power in the test chambers.

4.9.2 Water sprinkler deactivation.

Should an event occur where the smoke alarms have been falsely triggered, it will be necessary to deactivate the water sprinkler system. **NOTE: This action has to be accomplished within 30 seconds of the METF fire system alarm activation.**

At the Fire Alarm Abort switch directly in front of the METF entrance door, perform the following:

- Raise switch guard.
- Place switch to the up position to abort.
- Verify system aborted LED is on.

5. GENERAL REQUIREMENTS

5.1 Application of SL-E-0002 Book 3 Volume 1 Specification

SL-E-0002 Book 3 Volume 1 states that the requirements of SL-E-0002 Book 3 Volume 1 shall be applied to electronic, electrical and electromechanical equipment as indicated hereinafter.

The applicability of the emission and susceptibility requirements is dependent upon the types of equipment or subsystems and their intended installations. Table I (from SL-E-0002 Book 3 Volume 1) shows individual requirements applications based on equipment type or function. SL-E-0002 Book 3 Volume 1 states that Table I and notes thereto shall be used as a guide for test selection. For each procurement, SL-E-0002 Book 3 Volume 1 states that the activity shall specify the applicable tests from Table I.

TABLE I. Requirement Applicability.

Requirement/test method →	CE102	CE106	CS101	CS103	CS104	CS105	CS106	CS114	CS116	RE102	RE103	RS103	TT101
↓ Equipment type ↓ Note→		1		2	2	2		3	3, 6	4	1		5
Antenna-connected electronics, battery powered		X		X	X	X		X	X	X	X	X	
Antenna-connected electronics connected to Shuttle primary power source	X	X	X	X	X	X	X	X	X	X	X	X	X
Non-antenna connected electronics, battery powered								X	X	X		X	
Non-antenna connected electronics, connected to Shuttle primary power source	X		X				X	X	X	X		X	X
Electrical loads connected to Shuttle primary power without intermediate power conversion													X

Note 1: Either CE106 or RE103 applies, but not both. RE103 is performed when CE106 is not practical, as when the antenna cannot be disconnected from the transmitter/receiver, or when transmit power is too high to filter directly.

Note 2: Applies to radio frequency (RF) receivers and RF components between receiver and antenna (e.g., RF preamplifiers and down converters).

Note 3: Applies to cables connected to EUT only including power lines.

Note 4: RE102 includes a bulk current emission test, a measure of common mode currents on interconnect and power line wiring.

Note 5: TT101 applies to 28 VDC loads.

Note 6: Applicable for equipment that will not be lightning tested. Tailoring of requirements. Not applicable to Criticality 1 equipment that has been subjected to lightning transient testing.

5.1.1 Subsystems

SL-E-0002 Book 3 Volume 1 states that units or equipment within a single procurement subcontract shall be tested as a subsystem. Tests on individual units of the subsystem are not required unless directed by the procuring activity. (For this purpose, a subsystem would not normally be considered to be a spacecraft, launch vehicles or ground communication-electronic shelter.)

5.1.2 Government Furnished Equipment (GFE)

SL-E-0002 Book 3 Volume 1 states that equipment furnished by the government to a contractor may, unless the test data is furnished by the government, require testing by the contractor for conformance to the equipment item class and limit requirements. SL-E-0002 Book 3 Volume 1 states that the application of suppression measures to meet the requirements shall be detailed in the EMI Control Procedure (EMICP) (reference Paragraph 5.2.1).

5.1.3 Commercial Off-the-Shelf (COTS) Equipment

SL-E-0002 Book 3 Volume 1 states that when COTS equipment is selected by the contractor, all applicable tests shall be performed and the test data submitted to the procuring activity to determine the EMI/EMC compliance in the end item configuration. SL-E-0002 Book 3 Volume 1 states that the EMI/EMC compliance shall be covered in the EMICP (reference Paragraph 5.2.1).

5.1.4 Other EMI Requirements

5.1.4.1 Certification to Another EMI Requirements Document

Equipment qualified to other EMI specifications may be qualified to the requirements of SL-E-0002 Book 3 Volume 1 by a combination of analysis and/or test, as required to verify that the equipment meets the requirements of SL-E-0002 Book 3 Volume 1.

5.1.4.2 Additional Production

SL-E-0002 Book 3 Volume 1 states that all equipment, other than communication-electronic equipment, produced by a manufacturer, which are identical to those previously produced by the same manufacturer, tested in accordance with SL-E-0002 Book 3 Volume 1 and found satisfactory shall require minimal testing, as indicated in the approved test plan, to ascertain conformance with SL-E-0002 Book 3 Volume 1.SL-E-0002 Book 3 Volume 1 states that a copy of the previous rest report shall be forwarded with the new test report for comparison and evaluation.

5.1.5 Short-duration Interference

Short-duration interference is not exempt from the requirements of SL-E-0002 Book 3 Volume 1, unless specifically indicated in the individual equipment specification.

5.1.6 Self-compatibility

SL-E-0002 Book 3 Volume 1 states that the operational performance of an equipment or subsystem shall not be degraded, nor shall it malfunction, when all of the units or devices in the equipment or subsystem are operating together at their designated levels of efficiency or their design capability.

5.2 Documentation Requirements

5.2.1 Customer-prepared EMI Test Procedures (EMITP)

SL-E-0002 Book 3 Volume 1 states that an EMITP shall be prepared by the customer. The customer-prepared EMITP shall contain the following:

a. Introduction. The introduction of the EMITP shall include the following:
   1. A table describing all the tests to be performed, the applicable section within the EMITP, and the corresponding test procedure from SL-E-0002 Book 3 Volume 1.
   2. Description of the EUT, including its function, characteristics, intended installation, and power usage.
   3. Approved exceptions or deviations from contractual test requirements, if any.

b. Applicable documents. Applicable documents shall be listed as follows:
   1. NASA (such as standards and specifications).
   2. Military (such as standards and specifications).
   3. Company (such as in-house documents use for calibration or quality assurance).
   4. Other government or industry standards, specifications, and documents.

c. EUT setup. A description of the EUT setup for each test shall cover the following:
   1. Physical layout of the cables and EUT.
   2. Cable types, characteristics, and construction details (see Paragraph 5.3.8.6).
   3. Position of the LISNs on the ground plane.
   4. Use of bond straps
   5. Description of EUT loads.
   6. EUT simulation and monitoring equipment.
   7. The version of the software and firmware loaded into the EUT.

d. EUT operation. A description of the EUT operation shall cover the following:
   1. Modes of operation for each EMI subtest, including operating frequencies (where applicable), and rationale for selection of each mode.
   2. Control settings on the EUT.
   3. Control settings on any test stimulation and monitoring equipment and characteristics of input signals.
   4. Operating frequencies (such as oscillator and clock frequencies) which may be expected to approach limits.
   5. Performance checks initiated to designate the equipment minimal working standard requirements.
   6. Enumeration of circuits, outputs, or displays to be monitored during susceptibility testing, as well as the criteria for determining degradation of performance.

e. Measurements. The following shall be described for each test.
   1. Block diagram depicting test setup, including all pertinent dimensions.
   2. Step-by-step procedures to operate the EUT for each EMI subtest.

5.2.2 Customer-prepared EMI Test Report (EMITR)

SL-E-0002 Book 3 Volume 1 states that an EMITR shall be prepared by the customer. The customer-prepared EMITR shall contain the following:

a.. Contract number.
b. Authentication and certification of performance of the tests by a qualified representative of the procuring authority, if required.
c. Disposition of the EUT.
d. Description of the EUT, including its function, characteristics, intended installation, actual cable types (characteristics and construction details, reference Paragraph 5.3.8.6), and electrical current usage on each power input line.
e. List of EMI tests performed with pass/fail indications.
f. Any approved deviations from contractual test procedures or limits previously authorized.
g. Identification of COTS and GFE that may be part of the EUT.
h. A reference to the approved customer-prepared EMITP.

5.2.3 METF-prepared EMI Test Report (EMITR)

An EMITR shall be prepared by METF. The METF-prepared EMITR shall contain the following:

a. A test summary including the following:
   1. An overall test summary and table of tests performed with pass/fail indications.
   2. A test results summary for each EMI subtest performed.
   3. A description of test requirements, setup, and test methods
   4. A test run log spreadsheet identifying each EMI run with a run number, plot/print number, which EMI subtest was performed, METF software used, whether the run was a record or troubleshooting run, the applicable frequency range tested for that run, the equipment face tested, the EUT lead under test, the METF antenna orientation, the susceptibility level tested, an indication of pass/fail for the run, effects/observations during the run, and the EUT test configuration for the run.
   5. An METF test checklist detailing each EMI subtest performed, the test method, the METF software used, and the applicable SL-E-0002 Book 3 Volume 1 test limit.
   6. Conclusions and recommendations. Conclusions and recommendations shall be provided, including results of the test in brief narrative form, a discussion of any remedial EUT actions or modifications initiated during the test, and suggested corrective measures (if necessary) to assure compliance of the equipment or subsystem with the contractual EMI requirements.

b. A copy of the completed and signed MSFC Form 4404 METF Customer Agreement Form (CAF)

c. Applicable customer-provided documentation for the EUT, including (as a minimum) a copy of the as-run red-lined customer-prepared EMITP used during the test.

d. The as-run red-lined MFOP-FA-EMI-304 EMI/EMC Facility Operating Procedure for SL-E-0002 Book 3 Volume 1 including the following:
   1. Test equipment nomenclature, MSFC calibration identification numbers, version of software used (if any), and the calibration due date.
   2. Transfer impedance of current probes
   3. Antenna factors
   4. Impedance values of LISNs.
   5. Sample calculations, such as conversions of measured levels for comparison against the applicable limit.

e. The test data, including the following:
   1. The ambient radiated and conducted electromagnetic emission profile of the METF, when necessary.
   2. Data, and data presentation, as specified in the "data presentation" sections of the individual test procedures of MFOP-FA-EMI-304.
   3. Scan speeds, if different than that specified in SL-E-0002 Book 3 Volume 1.
   4. Measurement receiver bandwidths, if different than that specified in SL-E-0002 Book 3 Volume 1.
   5. Antenna polarization.
   6. Power line voltages, frequencies, and power factor (where applicable).
   7. Low-noise amplifier compression points for RE102 measurements.
   8. Any thresholds of susceptibility which were determined.
   9. A copy of the test run log from the test summary section.

f. Captioned and labeled photographs of the actual test setup and EUT for each EMI subtest performed.

5.3 Verification requirements.
SL-E-0002 Book 3 Volume 1 states that the general requirements related to test procedures, test facilities, and equipment stated below, together with the detailed test procedures included in 6.0, shall be used to determine compliance with the applicable emission and susceptibility requirements of SL-E-0002 Book 3 Volume 1.

SL-E-0002 Book 3 Volume 1 states that any procuring activity approved exceptions or deviations from these general requirements shall be documented in the customer-prepared EMITP. Equipment that is intended to be operated as a subsystem shall be tested as such to the applicable EMI requirements whenever practical. Formal testing is not to commence without approval of the EMITP by the designated approving authority. Data that is gathered as a result of performing tests in one electromagnetic discipline may be sufficient to satisfy requirements in another. Therefore, to avoid unnecessary duplication, a single test program should be established with tests for similar requirements conducted concurrently whenever possible.

5.3.1 Measurement tolerances.

Unless otherwise stated for a particular measurement, the tolerance shall be as follows:

a. Distance: ±5%

b. Frequency: ±2%

c. Amplitude, measurement receiver: ±2 dB

d. Amplitude, measurement system (includes measurement receivers, transducers, cables, and so forth): ±3 dB

e. Time (waveforms): ±5%

f. Resistors: ±5%

e. Capacitors: ±20%

5.3.2 Shielded enclosures.

To prevent interaction between the EUT and the outside environment, shielded enclosures will usually be required for testing. These enclosures prevent external environment signals from contaminating emission measurements and susceptibility test signals from interfering with electrical and electronic items in the vicinity of the test facility. Shielded enclosures must have adequate attenuation such that the ambient requirements of 5.3.4 are satisfied. The enclosures must be sufficiently large such that the EUT arrangement requirements of paragraph 5.3.8 and antenna positioning requirements described in the individual test procedures are satisfied.

The MSFC EMI Test Facility (METF) is located in MSFC Building 4708 Room 1191. The facility consists of four shielded enclosures connected together as shown in Figure 1. The four shielded enclosures consist of a box level room, rack level room, instrumentation room, and an amplifier room. The large test chamber, used for testing systems and large test items, is 24 feet wide, 28 feet deep, and 20 feet high. This is designated as the rack shielded enclosure in Figure 1. The small test chamber, used for testing subsystems and small test items, is 20 feet wide, 28 feet deep, and 14 feet high. This is designated as the box shielded enclosure in Figure 1. The instrumentation room measures 12 feet wide, 18 feet deep, and 10 feet high. The amplifier room measures 12 feet wide, 10 feet deep, and 10 feet tall. All sides of each room are constructed of quarter inch steel plate.

The rack and box level chambers are fully lined with radio frequency (RF) absorber. The RF absorber characteristics are discussed in Section 4.3.2.1. Each test chamber has a large door for EUT delivery and a smaller personnel door. All doors are pneumatically sealed sliding doors that maintain the steel double-walled enclosure integrity. All door mating surfaces are flame sprayed with tin. Ceiling and wall penetrations include 21 sprinkler penetrations, 18 vent penetrations, 16 filter penetrations, and 5 access panels.

The box level and rack level shield room attenuation requirements are shown in Table II. The Instrumentation and Amplifier shield room attenuation requirements are shown in Table III. These requirements have been verified using the procedures of Specification NSA No. 65-6, National Security Agency Specification for R.F. Shielded Enclosures for Communications Equipment: General Specification. Both box level and rack level test chamber ambient RE102 and RE101 levels are a minimum of 6dB below the MIL-STD-461E limits.

TABLE II. METF box and rack room attenuation requirements.

Frequency	Field Type	Attenuation (dB)
60 Hz	Magnetic	24
1 kHz	Magnetic	20
15 kHz	Magnetic	75
250 kHz	Magnetic	100
1 MHz	Magnetic	100
30 Hz	Electric	25
1 kHz	Electric	70
10 kHz	Electric	100
100 kHz	Electric	100
1 MHz	Electric	100
10 MHz	Electric	100
100 MHz	Plane Wave	100
400 MHz	Plane Wave	100
1 GHz	Plane Wave	100
12 GHz	Plane Wave	100

TABLE III. METF instrumentation and amplifier room attenuation requirements.

Frequency	Field Type	Attenuation (dB)
1 kHz	Magnetic	20
10 kHz	Magnetic	55
100 kHz	Magnetic	90
1 MHz	Magnetic	100
1 kHz	Electric	70
10 kHz	Electric	100
100 kHz	Electric	100
1 MHz	Electric	100
10 MHz	Electric	100
100 MHz	Plane Wave	100
400 MHz	Plane Wave	100
1 GHz	Plane Wave	100
12 GHz	Plane Wave	100

5.3.3 Radio Frequency (RF) absorber material.

SL-E-0002 Book 3 Volume 1 states that RF absorber material (carbon impregnated foam pyramids, ferrite tiles, and so forth) shall be used when performing electric field radiated emissions or radiated susceptibility testing inside a shielded enclosure to reduce reflections of electromagnetic energy and to improve accuracy and repeatability. The RF absorber shall be placed above, behind, and on both sides of the EUT, and behind the radiating or receiving antenna as shown in Figure 2. Minimum performance of the material shall be as specified in Table IV. The manufacturer's certification of their RF absorber material (basic material only, not installed) is acceptable.

TABLE IV. Absorption at normal incidence.

Frequency	Minimum absorption
80 MHz - 250 MHz	6 dB
above 250 MHz	10 dB

METF utilizes Advanced Electromagnetics Incorporated (AEMI) AEP-12 12 inch pyramidal absorber on all walls and ceiling in each test chamber. This exceeds the SL-E-0002 Book 3 Volume 1 spatial coverage required in Figure 2. The absorption at normal incidence is plotted versus the MIL-STD-461E requirement in Figure 3. Note that the absorber does not meet the MIL-STD-461E absorption requirements in the 80 MHz-100 MHz frequency range. At 80 MHz the METF absorber provides 3.5 dB attenuation, rather than the required 6 dB. This is 2.5dB below the requirement. The 2.5 dB difference becomes 0 dB by 100MHz. In the 100MHz-20GHz frequency range the METF absorber greatly exceeds the MIL-STD-461E absorption requirements.

5.3.4 Ambient electromagnetic level.

SL-E-0002 Book 3 Volume 1 states that during testing, the ambient electromagnetic level measured with the EUT de-energized and all auxiliary equipment turned on shall be at least 6 dB below the allowable specified limits when the tests are performed in a shielded enclosure. Ambient conducted levels on power leads shall be measured with the leads disconnected from the EUT and connected to a resistive load which draws the same rated current as the EUT. When tests are performed in a shielded enclosure and the EUT is in compliance with required limits, the ambient profile need not be recorded in the METF-prepared EMITR. However, it the ambient profile is recorded it should be included in the METF-prepared EMITR. When measurements are made outside a shielded enclosure, the tests shall be performed during times and conditions when the ambient is at its lowest level. The ambient shall be recorded in the METF-prepared EMITR and shall not compromise the test results.

5.3.5 Ground plane.

SL-E-0002 Book 3 Volume 1 states that the EUT shall be installed on a ground plane that simulates the actual installation. If the actual installation is unknown or multiple installations are expected, then a metallic ground plane shall be used. Unless otherwise specified below, ground planes shall be 2.25 square meters or larger in area with the smaller side no less than 76 centimeters. When a ground plane is not present in the EUT installation, the EUT shall be placed on a non-conductive table.

5.3.5.1 Metallic ground plane.

SL-E-0002 Book 3 Volume 1 states that when the EUT is installed on a metallic ground plane, the ground plane shall have a surface resistance no greater than 0.1 milliohms per square. The DC resistance between metallic ground planes and the shielded enclosure shall be 2.5 milliohms or less. The metallic ground planes shown in Figures 2 through 5 shall be electrically bonded to the floor or wall of the basic shielded room structure at least once every 1 meter. The metallic bond straps shall be solid and maintain a five-to-one ratio or less in length to width. Metallic ground planes used outside a shielded enclosure shall extend at least 1.5 meters beyond the test setup boundary in each direction.

Each METF test chamber has a non-conductive EUT test table with 90cm height. The tabletop is completely covered by 1/8" copper stock. The copper tabletop is bonded to the shielded enclosure every 35.5" with 1/16" copper stock straps which are 12" wide and less than 59" long. This provides a good RF bond between the test tabletop and the shielded enclosure. The nominal tabletop size is 8 ft long by 3 ft wide, but can be extended to 12 ft long by 6 ft wide for large test items.

For EUTs with metal enclosures mounted to a metal structure in the actual equipment installation, the EUT is bonded to the copper table top using contact between the EUT and the tabletop and either a braided metal strap or copper tape. The bonding simulates the actual installation as closely as possible.

5.3.5.2 Composite ground plane.

SL-E-0002 Book 3 Volume 1 states that when the EUT is installed on a conductive composite ground plane, the surface resistivity of the typical installation shall be used. Composite ground planes shall be electrically bonded to the enclosure with means suitable to the material. It shall be the responsibility of the test customer to provide the composite ground plane meeting these requirements.

5.3.6 Power source impedance.

The impedance of power sources providing input power to the EUT shall be controlled by Line Impedance Stabilization Networks (LISNs) for all measurement procedures of this document unless otherwise stated in a particular test procedure. LISNs shall not be used on output power leads. The LISNs shall be located at the power source end of the exposed length of power leads specified in paragraph 5.3.8.6.2. Two different LISNs are required in this specification. The LISN circuit for all tests except TT101 shall be in accordance with the schematic shown in Figure 6. The LISN impedance characteristics shall be in accordance with Figure 7. The LISN impedance shall be measured at least annually under the following conditions:

a. The impedance shall be measured between the power output lead on the load side of the LISN and the metal enclosure of the LISN.

b. The signal output port of the LISN shall be terminated in fifty ohms.

c. The power input terminal on the power source side of the LISN shall be unterminated.

Impedance characteristics and circuitry for the TT101 LISN is described in that test section. The LISN impedance shall be measured at least annually under the following conditions:

a. The impedance shall be measured between the positive and negative power output leads on the load side of the LISN.

b. The positive and negative power input terminals on the power source side of the LISN shall be shorted together.

The impedance measurement results shall be provided in the METF-prepared EMITR.

METF utilizes two independent power supplies to provide dc power inside the test chambers. The power supplies are located in room E-20 on the second floor on top of the test chambers. The power supply feeds come down from the second floor to filters mounted on the outside of each test chamber. The first power supply is usually used to provide 120Vdc power. This supply is an Electronic Measurement Inc. model EMHP 300-100-41211, serial number 92K-1233 and is rated at 300V/100A. This power supply feeds into the chamber via Lectro Line (Lectrometrics Division of Lindgren RF Enclosures) LMX-UL-100A, 100A, 277VAC line to ground 50/60Hz (9244) filters on each power leg at the outer chamber wall of each chamber. The second power supply is usually used to provide 28Vdc power. This supply is an Electronic Measurement Inc model TCR 40570-2-D-OV (serial number 92H-7770) and is rated at 40V/70A. This power supply feeds into the chambers via Lectro Line (Lectrometrics Division of Lindgren RF Enclosures) LMX-UL-20A, 20A, 277VAC line to ground 50/60Hz (9244) filters on each power leg at the outer chamber wall of each chamber. 208VAC and 115VAC power is fed into the chambers via Lectro Line (Lectrometrics Division of Lindgren RF Enclosures) LMX-UL-60A, 60Amp, 277VAC line to ground 50/60Hz (9244) filters on each power leg at the outer chamber wall of each chamber.

5.3.7 General test precautions.

5.3.7.1 Accessory equipment.
Accessory equipment used in conjunction with measurement receivers shall not degrade measurement integrity.

5.3.7.2 Excess personnel and equipment.
The test area shall be kept free of unnecessary personnel, equipment, cable racks, and desks. Only the equipment essential to the test being performed shall be in the test area or enclosure. Only personnel actively involved in the test shall be permitted in the enclosure.

5.3.7.3 Overload precautions.
Measurement receivers and transducers are subject to overload, especially receivers without preselectors and active transducers. Periodic checks shall be performed to assure that an overload condition does not exist. Instrumentation changes shall be implemented to correct any overload condition.

5.3.7.4 RF hazards.
Some tests in this specification will result in electromagnetic fields which are potentially dangerous to personnel. The permissible exposure levels in IEEE C95.1-1991, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3kHz to 300 Gigahertz (GHz), shall not be exceeded in areas where personnel are present. Safety procedures and devices shall be used to prevent accidental exposure of personnel to RF hazards.

5.3.7.5 Shock hazard.
Some of the tests require potentially hazardous voltages to be present. Extreme caution must be taken by all personnel to assure that all safety precautions are observed.

5.3.7.6 Federal Communications Commission (FCC) restrictions.
SL-E-0002 Book 3 Volume 1 states that all planned open site radiation tests (i.e. outside of shielded enclosures) shall be pre-coordinated and approved by the National Telecommunications and Information Administration (NTIA) and/or the FCC, whichever is applicable, regardless of the level of signals used. SL-E-0002 Book 3 Volume 1 states that authorization shall be secured prior to conducting the test readiness review. The test sponsor(s) and customers and the METF personnel shall contact the respective NASA Field Center Spectrum Manager at the earliest possible stage of the test planning with all pertinent RF systems parameters and configuration data to facilitate the authorization process.

5.3.8 EUT test configurations.

The EUT shall be configured as shown in the general test setups of Figures 1 through 5 as applicable. These setups shall be maintained during all testing unless other direction is given for a particular test procedure.

5.3.8.1 EUT design status.

SL-E-0002 Book 3 Volume 1 states that EUT hardware and software shall be representative of production. Software may be supplemented with additional code that provides diagnostic capability to assess performance.

5.3.8.2 Bonding of EUT.

Only the provisions included in the design of the EUT shall be used to bond units such as equipment case and mounting bases together, or to the ground plane. When bonding straps are required, they shall be identical to those specified in the installation drawings.

5.3.8.3 Shock and vibration isolators.

EUTs shall be secured to mounting bases having shock or vibration isolators if such mounting bases are used in the installation. The bonding straps furnished with the mounting base shall be connected to the ground plane. When mounting bases do not have bonding straps, bonding straps shall not be used in the test setup.

5.3.8.4 Safety grounds.

When external terminals, connector pins, or equipment grounding conductors are available for safety ground connections and are used in the actual installation, they shall be connected to the ground plane. Arrangement and length shall be in accordance with 5.3.8.6.1.

5.3.8.5 Orientation of EUTs.

SL-E-0002 Book 3 Volume 1 states that EUTs shall be oriented such that surfaces which produce maximum radiated emissions and respond most readily to radiated signals face the measurement antennas. Bench mounted EUTs shall be located 10 ±2 centimeters from the front edge of the ground plane subject to allowances for providing adequate room for cable arrangement as specified below.

5.3.8.6 Construction and arrangement of EUT cables.

SL-E-0002 Book 3 Volume 1 states the following:

Electrical cable assemblies shall simulate actual installation and usage. Shielded cables or shielded leads (including power leads and wire grounds) within cables shall be used only if they have been specified in installation requirements. Cables shall be checked against installation requirements to verify proper construction techniques such as use of twisted pairs, shielding, and shield terminations. Details on the cable construction, such as wire types, lengths, pigtail lengths, shield termination, lengths of ground wires, and ground locations, used for testing shall be included in the customer-prepared EMITP.

5.3.8.6.1 Interconnecting leads and cables.

SL-E-0002 Book 3 Volume 1 states:

Individual leads shall be grouped into cables in the same manner as in the actual installation. Interconnecting cable lengths in the test setup shall represent the actual lengths in the SSV, unless the actual vehicle lengths are less than that allowed to meet the following conditions. Cable lengths, when not specified for the installation, shall be sufficiently long to achieve a two meter run along the ground plane edge. At least the first 2 meters of each interconnecting cable associated with each enclosure of the EUT shall be run parallel to the front boundary of the setup. Remaining cable lengths shall be routed to the back of the setup and shall be placed in a zig-zagged arrangement. When the setup includes more than one cable, individual cables shall be separated by 2 centimeters measured from their outer circumference. For bench top setups using ground planes, cables shall be placed 10 centimeters from the front edge of the ground plane. All cables shall be supported 5 centimeters above the ground plane.

5.3.8.6.2 Input power leads.

Two meters of input power leads (including neutrals and returns) shall be routed parallel to the front edge of the setup in the same manner as the interconnecting leads. Each input power lead, including neutrals and returns, shall be connected to a LISN (see 5.3.6). Power leads that are bundled as part of an interconnecting cable in the actual installation shall be configured in the same fashion for the 2 meter exposed length and then shall be separated from the bundle and routed to the LISNs. After the 2 meter exposed length, the power leads shall be terminated at the LISNs in as short a distance as possible. The total length of power lead from the EUT electrical connector to the LISNs shall not exceed 2.5 meters. All power leads shall be supported 5 centimeters above the ground plane. If the power leads are twisted in the actual installation, they shall be twisted up to the LISNs.

5.3.8.7 Electrical and mechanical interfaces.

SL-E-0002 Book 3 Volume 1 states:

All electrical input and output interfaces shall be terminated with either the actual equipment from the platform installation or loads external to the EUT which simulate the electrical properties (impedance, grounding, balance, and so forth) present in the actual installation. Signal inputs shall be applied to all applicable electrical interfaces to exercise EUT circuitry. EUTs with mechanical outputs shall be suitably loaded. When variable electrical or mechanical loading is present in the actual installation, testing shall be performed under expected worst case conditions. When active electrical loading (such as a test set) is used, precautions shall be taken to insure the active load meets the ambient requirements of Paragraph 5.3.4 when connected to the setup, and that the active load does not respond to susceptibility signals. Antenna ports on the EUT shall be terminated with shielded, matched loads.

5.3.9 Operation of EUT.

SL-E-0002 Book 3 Volume 1 states:
During emission measurements, the EUT shall be placed in an operating mode which produces maximum emissions. During susceptibility testing, the EUT shall be placed in its most susceptible operating mode. For EUTs with several available modes (including software controlled operational modes), a sufficient number of modes shall be tested for emissions and susceptibility such that all circuitry is evaluated. If production software or firmware is not available, justification shall be shown that the software or firmware used for the test is able to activate or exercise the EUT in a manner equivalent to production software or firmware. The rationale for modes selected shall be included in the customer-prepared EMITP. A functional test of the EUT shall be performed as a minimum before and after the entire test series.

5.3.9.1 Operating frequencies for tunable RF equipment.

SL-E-0002 Book 3 Volume 1 states:
Measurements shall be performed with the EUT tuned to not less than three frequencies within each tuning band, tuning unit, or range of fixed channels, consisting of one mid-band frequency and a frequency within ±5 percent from each end of each band or range of channels.

5.3.9.2 Operating frequencies for spread spectrum equipment.

SL-E-0002 Book 3 Volume 1 states:
Operating frequency requirements for two major types of spread spectrum equipment shall be as follows:

a. Frequency hopping. Measurements shall be performed with the EUT utilizing a hop set which contains a minimum of 30% of the total possible frequencies. This hop set shall be divided equally into three segments at the low, mid, and high end of the EUT's operational frequency range.

b. Direct sequence. Measurements shall be performed with the EUT processing data at the highest possible data transfer rate.

5.3.9.3 Susceptibility monitoring.

SL-E-0002 Book 3 Volume 1 states:
The EUT shall be monitored during susceptibility testing for indications of degradation or malfunction. This monitoring is normally accomplished through the use of built-in-test (BIT), visual displays, aural outputs, and other measurements of signal outputs and interfaces. Monitoring of EUT performance through installation of special circuitry in the EUT is permissible; however, these modifications shall not influence test results.

5.3.10 Use of measurement equipment.

Measurement equipment shall be as specified in the individual test procedures of this specification. Any frequency selective measurement receiver may be used for performing the testing described in this standard provided that the receiver characteristics (that is, sensitivity, selection of bandwidths, detector functions, dynamic range, and frequency of operation) meet the constraints specified in this standard and are sufficient to demonstrate compliance with the applicable limits. Typical instrumentation characteristics may be found in ANSI C63.2, Standard for Instrumentation Electromagnetic Noise and Field Strength, 10kHz to 40GHz.

5.3.10.1 Detector.

A peak detector shall be used for all frequency domain emission and susceptibility measurements. This device detects the peak value of the modulation envelope in the receiver bandpass. Measurement receivers are calibrated in terms of an equivalent Root Mean Square (RMS) value of a sine wave that produces the same peak value. When other measurement devices such as oscilloscopes, non-selective voltmeters, or broadband field strength sensors are used for susceptibility testing, correction factors shall be applied for test signals to adjust the reading to equivalent RMS values under the peak of the modulation envelope.

5.3.10.2 Computer-controlled receivers.

SL-E-0002 Book 3 Volume 1 states:
A description of the operations being directed by software for computer-controlled receivers shall be included in the EMITP. Verification techniques used to demonstrate proper performance of the software shall also be included.

5.3.10.3 Emission testing.

5.3.10.3.1 Bandwidths.

The measurement receiver bandwidths listed in Table V shall be used for emission testing. These bandwidths are specified at the 6 dB down points for the overall selectivity curve of the receivers. Video filtering shall not be used to bandwidth limit the receiver response. If a controlled video bandwidth is available on the measurement receiver, it shall be set to its greatest value. Larger receiver bandwidths may be used; however, they may result in higher measured emission levels. NO BANDWIDTH CORRECTION FACTORS SHALL BE APPLIED TO TEST DATA DUE TO THE USE OF LARGER BANDWIDTHS.

TABLE V. Bandwidth and measurement time.

Frequency Range	6 dB Bandwidth	Dwell Time	Minimum Measurement Time Analog Measurement Receiver
30 Hz - 1 kHz	10 Hz	0.15 sec	0.015 sec/Hz
1 kHz - 10 kHz	100 Hz	0.015 sec	0.15 sec/kHz
10 kHz - 150 kHz	1 kHz	0.015 sec	0.015 sec/kHz
150 kHz - 30 MHz	10 kHz	0.015 sec	1.5 sec/MHz
30 MHz - 1 GHz	100 kHz	0.015 sec	0.15 sec/MHz
Above 1 GHz	1 MHz	0.015 sec	15 sec/GHz

5.3.10.3.2 Emission identification.

All emissions regardless of characteristics shall be measured with the measurement receiver bandwidths specified in Table V and compared against the applicable limits. Identification of emissions with regard to narrowband or broadband categorization is not applicable.

5.3.10.3.3 Frequency scanning.

For emission measurements, the entire frequency range for each applicable test shall be scanned. Minimum measurement time for analog measurement receivers during emission testing shall be as specified in Table V. Synthesized measurement receivers shall step in one-half bandwidth increments or less, and the measurement dwell time shall be as specified in Table V. For equipment that operates such that potential emissions are produced at only infrequent intervals, times for frequency scanning shall be increased as necessary to capture any emissions. For equipment which operates for very short durations, or which has a limited life, scan times may be reduced. Justification for such reduction will be presented in the customer-prepared EMITP, and approved by the designated approving authority prior to test.

5.3.10.3.4 Emission data presentation.
Amplitude versus frequency profiles of emission data shall be automatically generated and displayed at the time of test and shall be continuous. The displayed information shall account for all applicable correction factors (transducers, attenuators, cable loss, and the like) and shall include the applicable limit. Manually gathered data is not acceptable except for verification of the validity of the output. Plots of the displayed data shall provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and minimum amplitude resolution of 1 dB. The above resolution requirements shall be maintained in the reported results of the METF-prepared EMITR.

5.3.10.4 Susceptibility testing.

5.3.10.4.1 Frequency scanning.
For susceptibility measurements, the entire frequency range for each applicable test shall be scanned. For swept frequency susceptibility testing, frequency scan rates and frequency step sizes of signal sources shall not exceed the values listed in Table VI. The rates and step sizes are specified in terms of a multiplier of the tuned frequency (f_o) of the signal source. Analog scans refer to signal sources which are continuously tuned. Stepped scans refer to signal sources which are sequentially tuned to discrete frequencies. Stepped scans shall dwell at each tuned frequency for the greater of 3 seconds or the EUT response time. Scan rates and step sizes shall be decreased when necessary to permit observation of a response.

TABLE VI. Susceptibility scanning.

Frequency Range	Analog Scans Maximum Scan Rates	Stepped Scans Maximum Step Size
30 Hz - 1 MHz	$0.0333f_o$/sec	$0.05\ f_o$
1 MHz - 30 MHz	$0.00667\ f_o$/sec	$0.01\ f_o$
30 MHz - 1 GHz	$0.00333\ f_o$/sec	$0.005\ f_o$
1 GHz - 8 GHz	$0.000667\ f_o$/sec	$0.001\ f_o$
8 GHz - 40 GHz	$0.000333\ f_o$/sec	$0.0005\ f_o$

5.3.10.4.2 Modulation of susceptibility signals.
Susceptibility modulation requirements are located with the susceptibility requirement. If pulse modulation is not available below 1 GHz, amplitude modulation at 99% depth shall be substituted. With this option, care shall be exercised that the peak of the modulation envelope corresponds to the limit level stress.

5.3.10.4.3 Thresholds of susceptibility.
SL-E-0002 Book 3 Volume 1 states:
When susceptibility indications are noted in EUT operation, a threshold level shall be determined where the susceptible condition is no longer present. Thresholds of susceptibility shall be determined as follows and described in the EMITR:

a. When a susceptibility condition is detected, reduce the interference signal until the EUT recovers.

b. Reduce the interference signal by an additional 6 dB.

c. Gradually increase the interference signal until the susceptibility condition reoccurs. The resulting level is the threshold of susceptibility.

d. Record this level, frequency range of occurrence, frequency and level of greatest susceptibility, and other test parameters, as applicable.

5.3.11 Calibration of measuring equipment.
Test equipment and accessories required for measurement in accordance with SL-E-0002 Book 3 Volume 1 shall be calibrated in accordance with ANSI/NCSL Z540-1, General Requirements for Calibration Laboratories and Measuring and Test Equipment, or ISO 10012-1, Quality Assurance Requirements for Measuring Equipment, or under an approved calibration program traceable to the National Institute for Standards and Technology (NIST). METF equipment is calibrated under an the approved calibration program, delineated in MPG 8730.5, Control of Inspection, Measuring, and Test Equipment, that is traceable to NIST. In particular, measurement antennas, current probes, field sensors, and other devices used in the measurement loop shall be calibrated at least every 2 years unless otherwise specified by the procuring activity, or when damage is apparent.

5.3.11.1 Measurement system test.
At the start of each emission test, the complete test system (including measurement receivers, cables, attenuators, couplers, and so forth) shall be verified by injecting a known signal, as stated in the individual test procedure, while monitoring system output for the proper indication. When the emission test involves an uninterrupted set of repeated measurements (such as evaluating different operating modes of the EUT) using the same measurement equipment, the measurement system test needs to be accomplished only one time.

5.3.11.2 Antenna factors.
Factors for test antennas shall be determined in accordance with SAE ARP-958, Electromagnetic Interference Measurement Antennas, Standard Calibration Requirements and Methods.

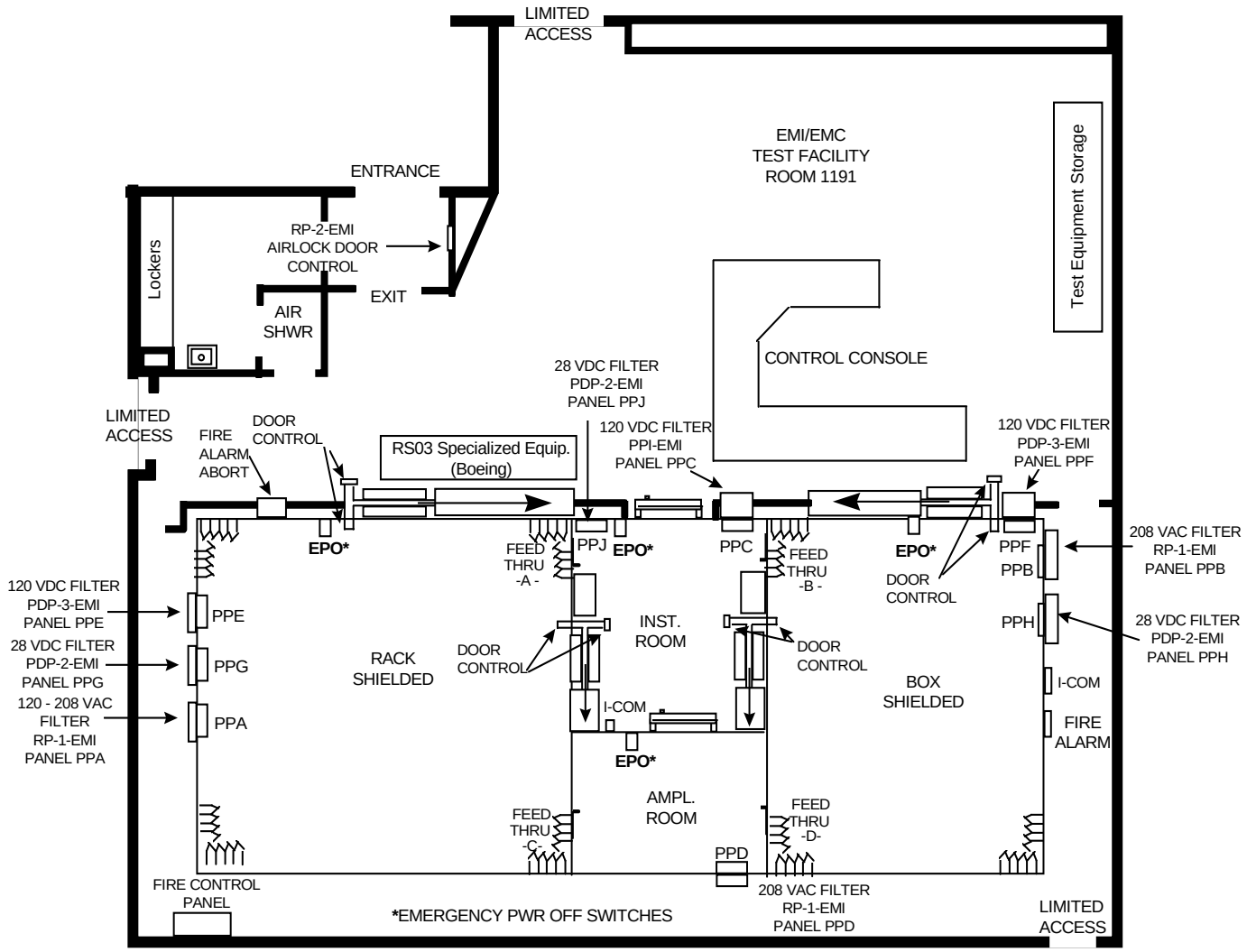

FIGURE 1. MSFC EMI Test Facility.

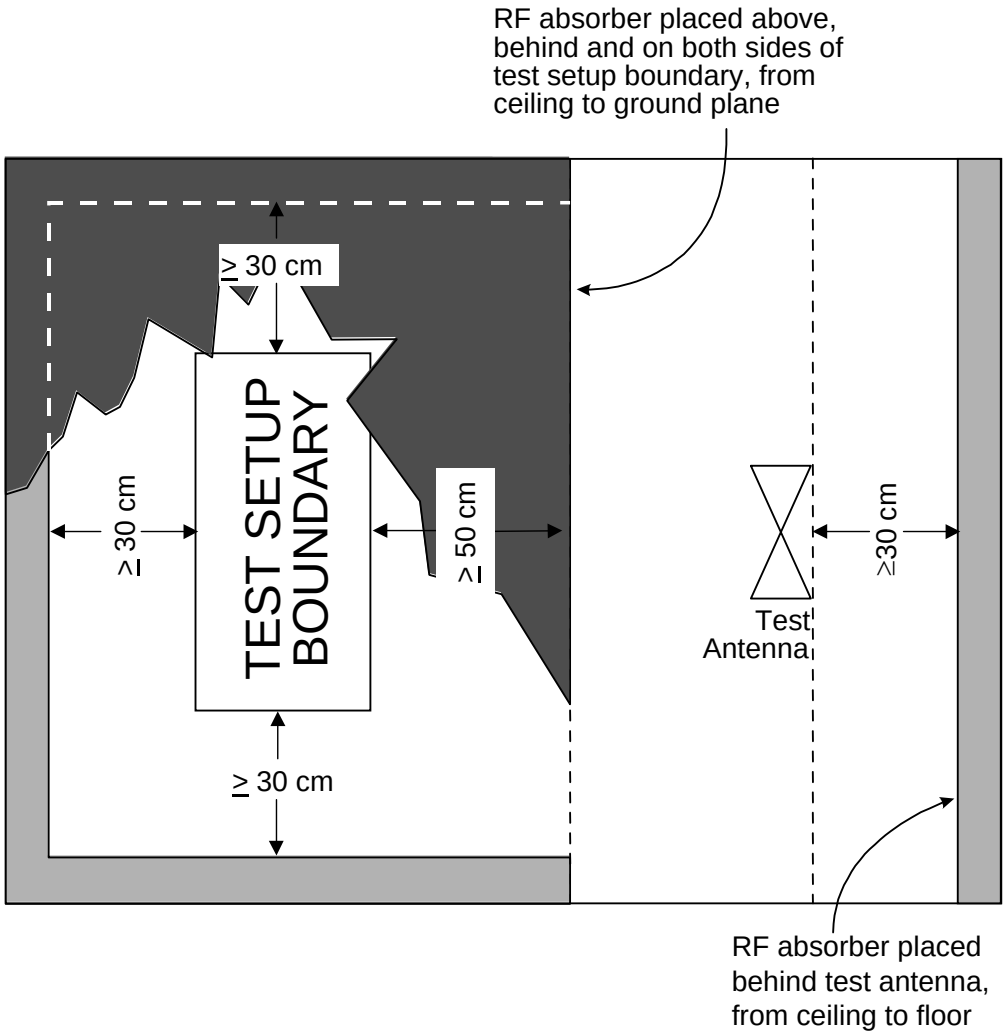

FIGURE 2. RF absorber loading diagram.

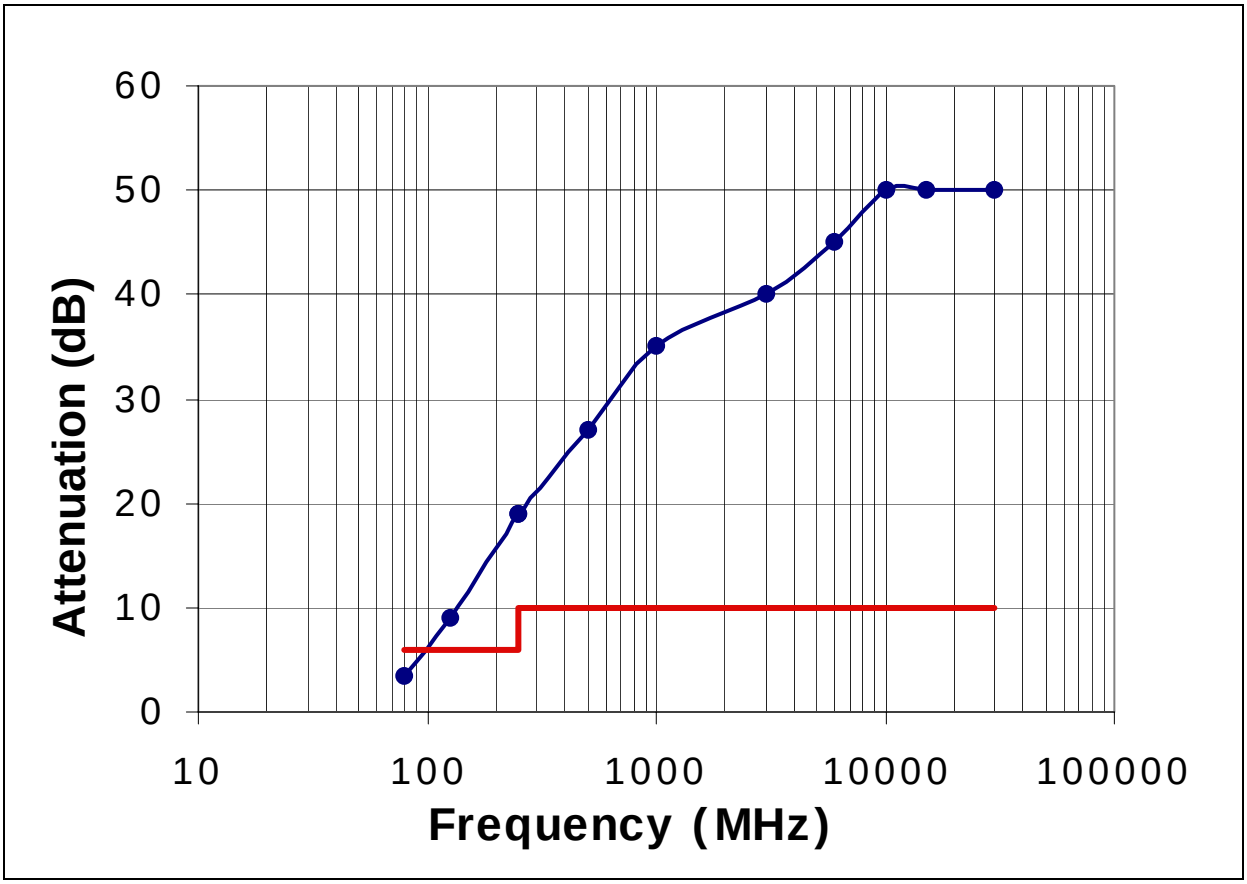

FIGURE 3. METF pyramidal absorber characteristics.

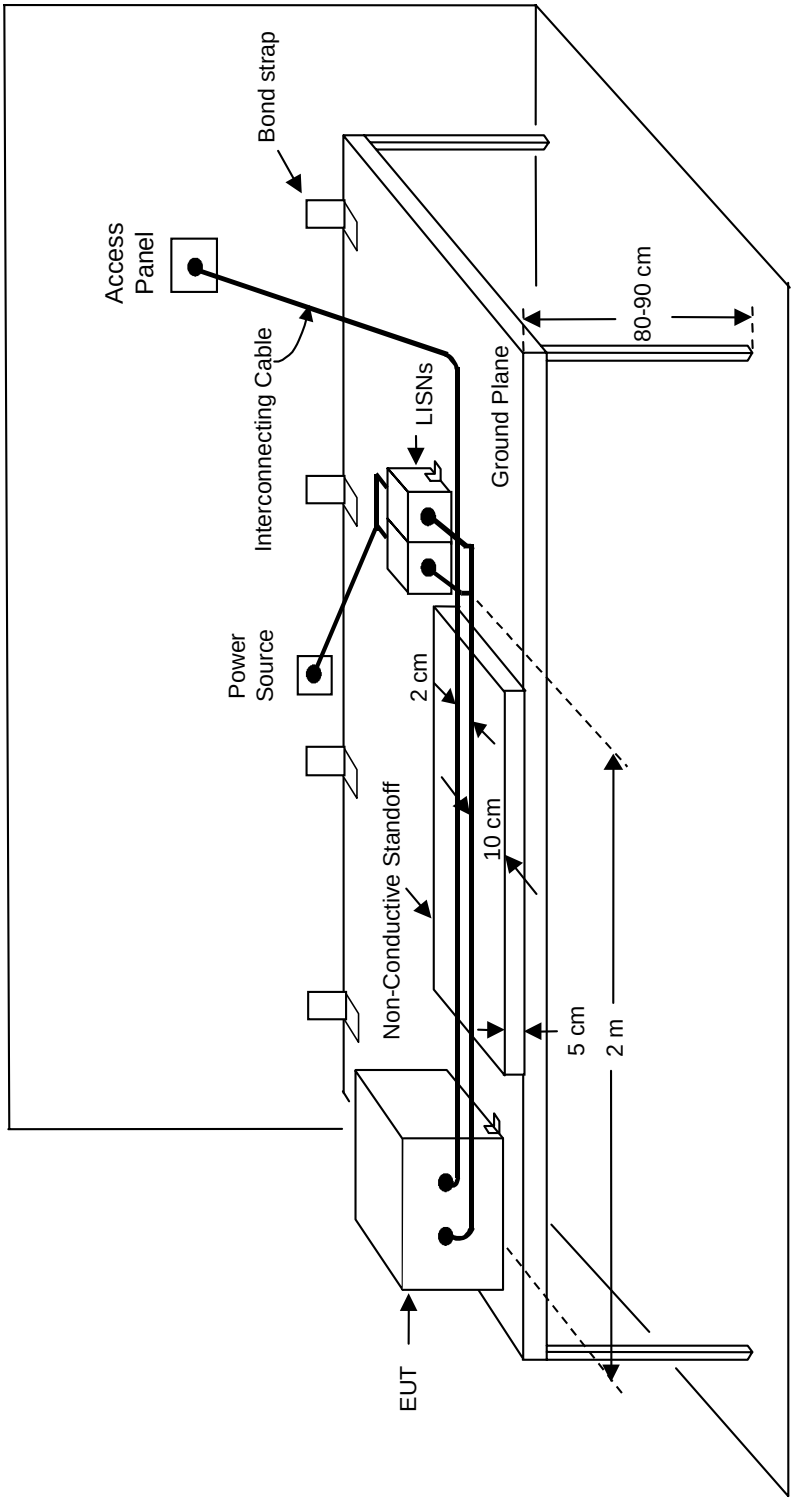

FIGURE 4. General test setup.

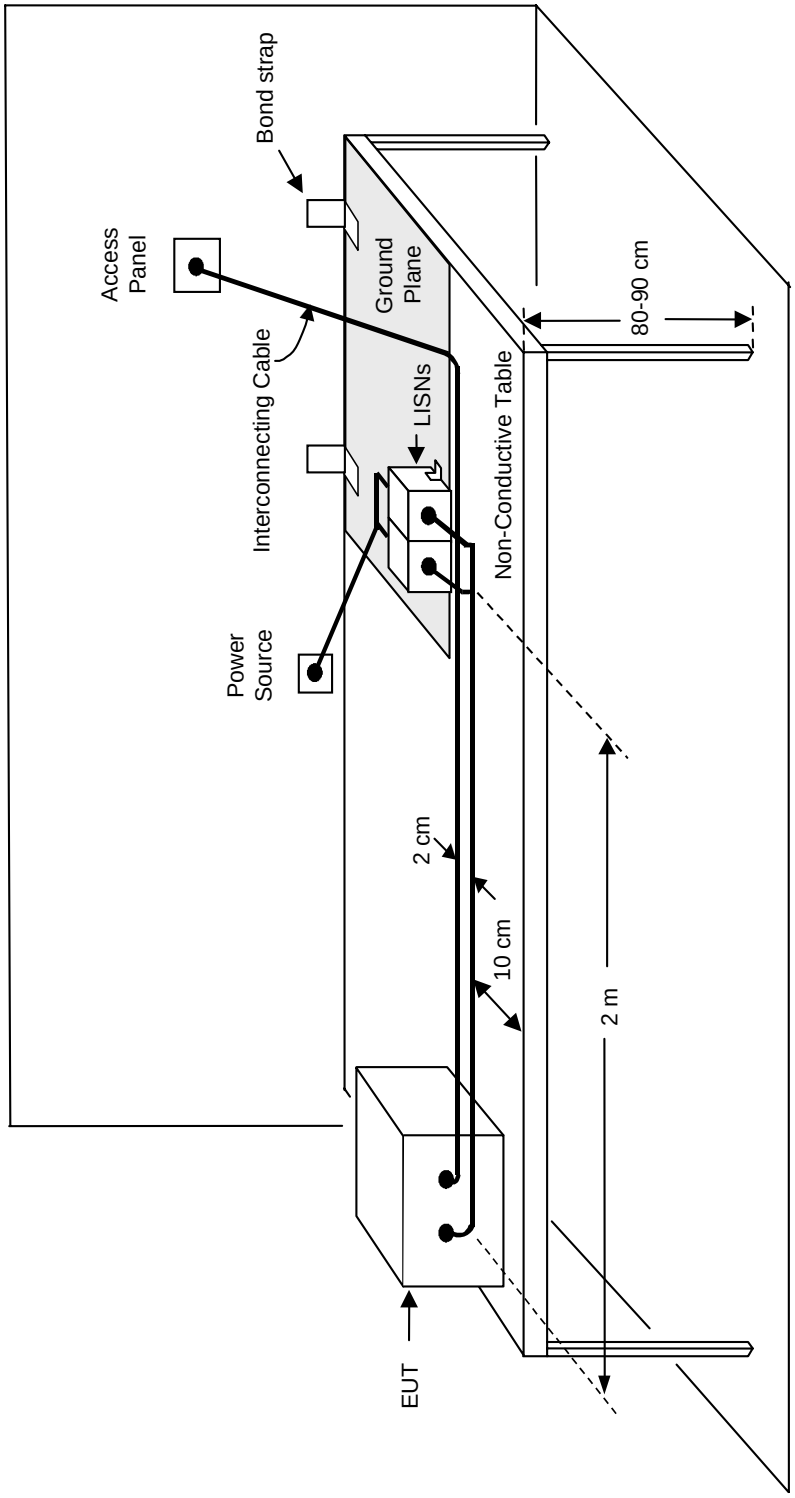

FIGURE 5. Test setup for non-conductive surface mounted EUT.

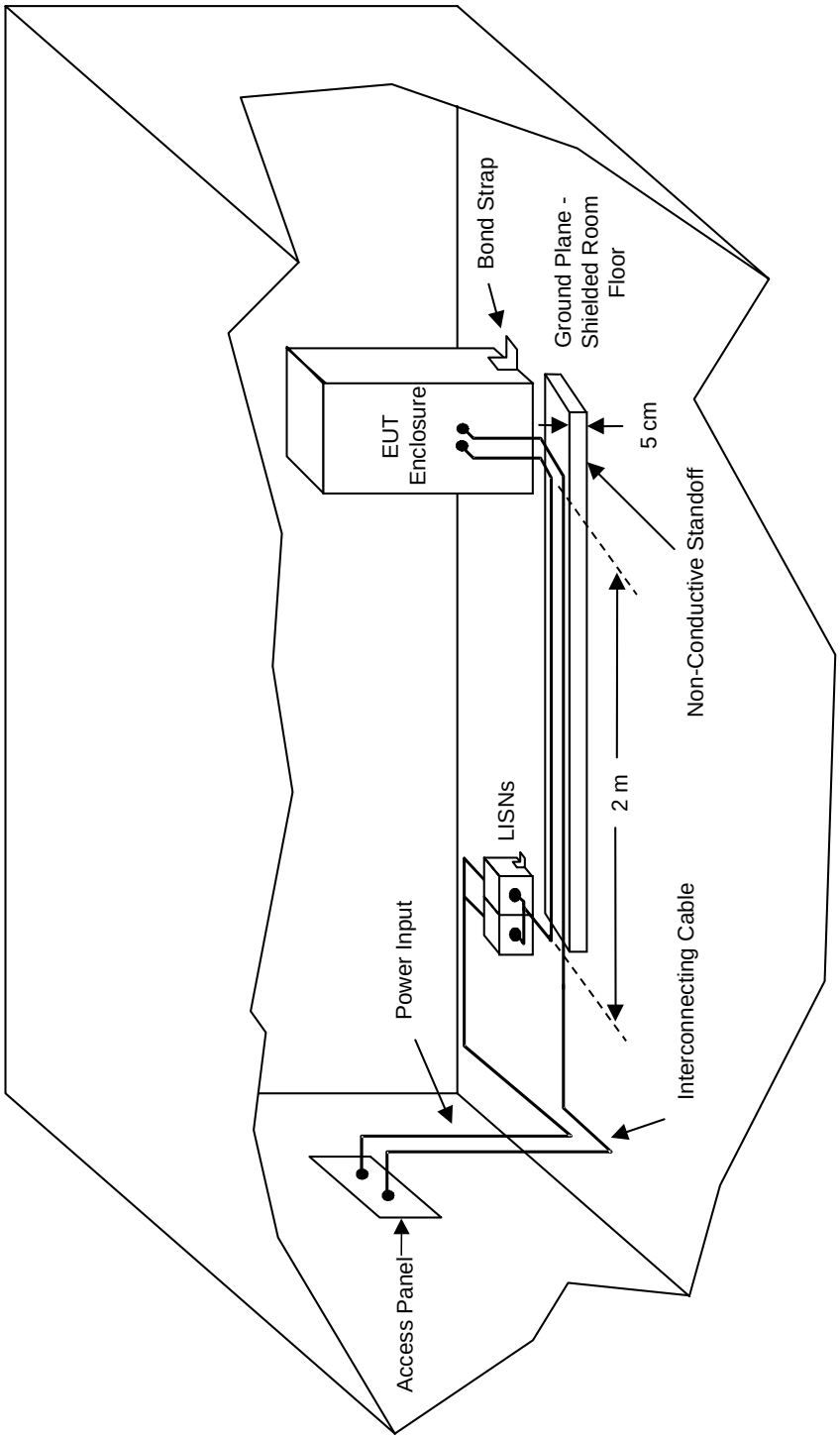

FIGURE 6. Test setup for free standing EUT in shielded enclosure.

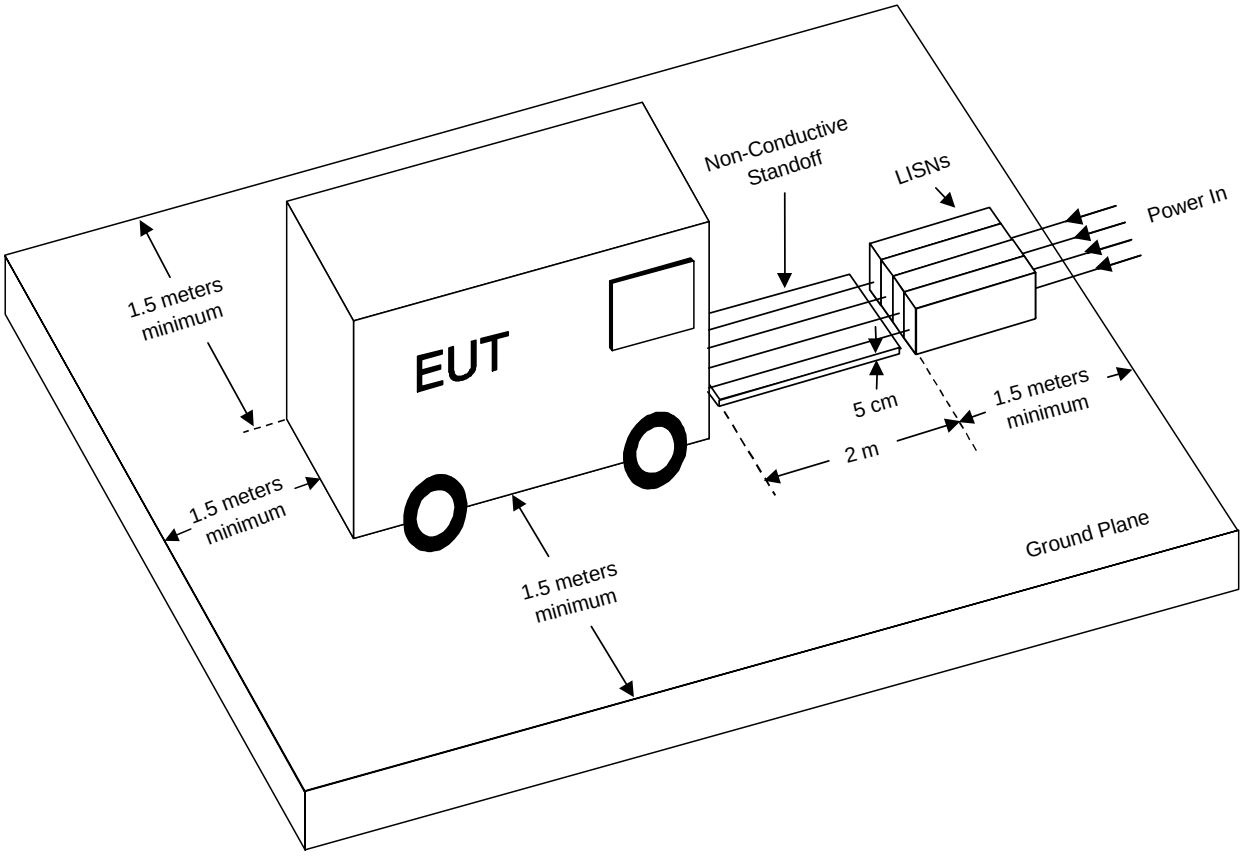

FIGURE 7. Test setup for free standing EUT.

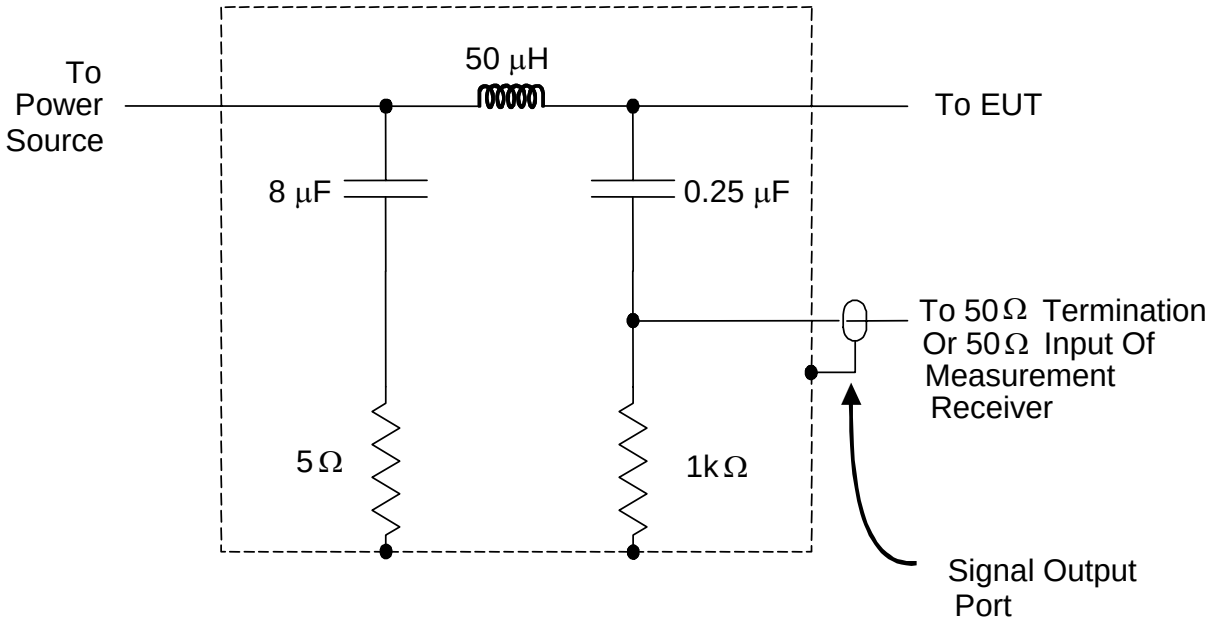

FIGURE 8. LISN schematic.

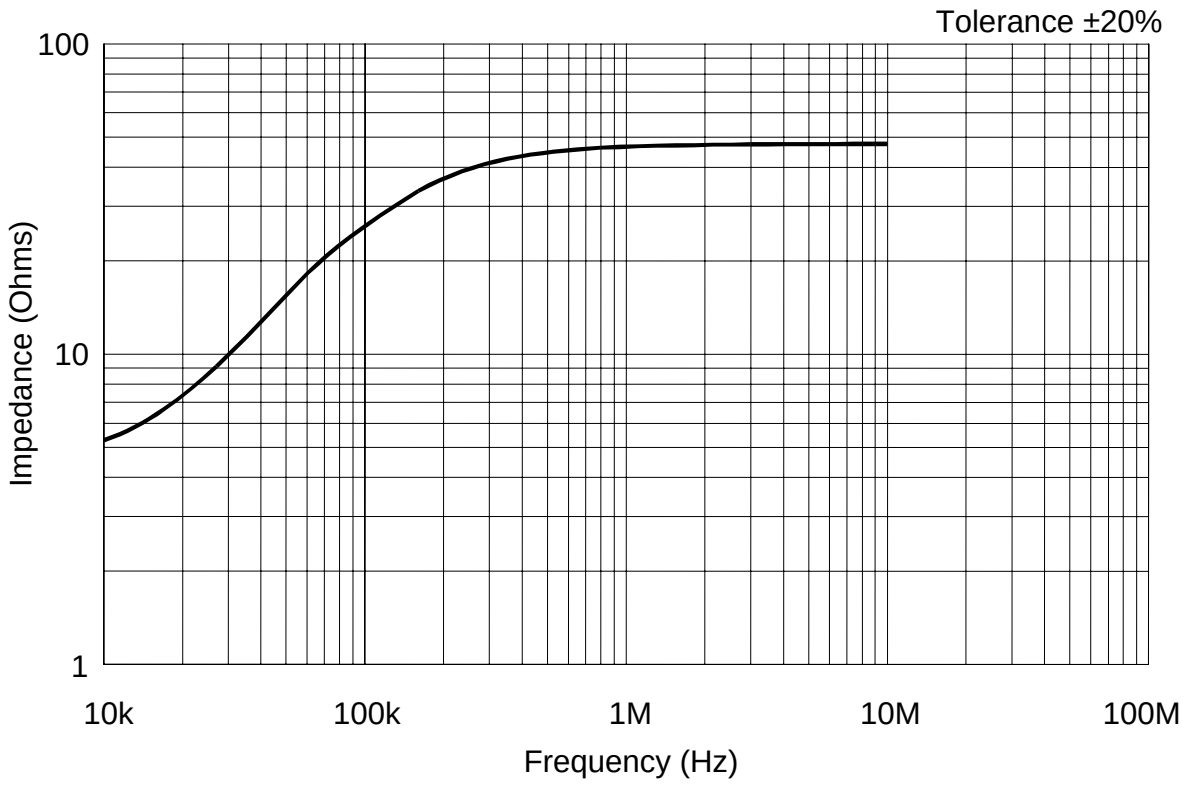

FIGURE 9. LISN impedance.

5.3.11.3 EUT Test Preparation Sheet
Sheet 1 of 2

CA Start Date: _____
Setup Date: _____
Start of test Date: _____
End of test Date : _____

Project Name: _____

Customer Agreement Number _____

EUT Product Number: _____ **EUT S/N**: _____

CSP Tag Number : _____

EUT EMI Test Preparations:

1. EUT bonding to ground plane measurement: _____mOhm (≤ 2.5 mohm)
   Other bonding values : _____
   _____

2. EUT measured current draw: _____

3. Install power fuse as required:

	120Vdc	28Vdc	12Vdc	-12Vdc	5Vdc
	____A	____A	____A	____A	____A

4.

METF Power Supply voltage	120Vdc	28Vdc	12Vdc	-12Vdc	5Vdc
Unloaded value:	____Vdc	____Vdc	____Vdc	____Vdc	____Vdc
Loaded value:	____Vdc	____Vdc	____Vdc	____Vdc	____Vdc

5. MIL-STD-461E Line Impedance Stabilization Networks (LISNs) installed on all EUT input power leads, LISNs are calibrated, and calibration factors have been included in the test procedure.

Power Bus 1	Power Bus 2	Power Bus 3	Power Bus 4
_____	_____	_____	_____

EUT Test Conductor: _____Date: _____
EI24 E3 Test Conductor :_____ Date: _____

EUT Test Preparation Sheet **Sheet 2 of 2**

Project Name: _____

EUT EMI Test Preparations (continued):

6 Line Impedance Stabilization Networks (LISNs) shall be bonded to the ground plane. Measure bonding values and record below.

Power Bus 1	Power Bus 2	Power Bus 3	Power Bus 4
_____	_____	_____	_____

7 EUT configured per the general test setups of Figures 4-7 in this FOP.

a. All sides of EUT at least 30 cm from test chamber wall _____
b. Front of EUT located 10cm from ground plane front edge _____
c. EUT safety grounds connected to ground plane (if applicable) _____
d. Interconnecting leads/cables (ILC) elevated 5 cm off gnd plane _____
e. ILC at front of table 10cm back from edge _____
f. At least 2 meters of each ILC parallel to table front edge _____
g. ILC longer than 10 meters, at least 10 meters tested _____
h. Remaining ILC lengths routed to back and zig-zagged _____
i. Individual ILCs separated by 2 cm _____
j. ILCs leaving test chamber have cable shield bonded to chamber _____
k. Power leads (PL) elevated 5 cm off ground plane _____
l. PL at front of table 10 cm back from edge _____
m. At least 2 meters of each PL parallel to table front edge _____
n. For bundled PL, 2 meters parallel to table front edge and then broken out and routed to LISN in as short a distance as possible _____
o. Total PL length less than 2.5 meters _____
p. Each PL (hot, return, neutral) connected to a LISN _____

Deviations from the above requirements: _____
_____
_____
_____
_____
_____

EUT Test Conductor: _____Date: _____
EI24 E3 Test Conductor :_____ Date: _____

5.3.11.4 Calibrated METF equipment used to perform this test

EI24 Electromagnetic Environmental Effects (E3) Team
NASA MSFC EMI Test Facility (METF)
Building 4708, room 1191

Date:_____ Project Name: _____ Sheet 1 of 6

Nomenclature:	Model	Cal ID	Cal Due Date
Current Measurement Probes			
RF Current Probe	Solar 6741-1	M649672	_____
RF Current Probe	Solar 6741-1	M650552	_____
RF Current Probe	Solar 6741-1	M649609	_____
RF Current Probe	Solar 9123-1N	M650517	_____
RF Current Probe	Solar 9123-1N	M650518	_____
RF Current Probe	EMCO 91550-2	M639667	_____
RF Current Probe	EMCO 91550-2BL	M636916	_____
RF Current Probe	EMCO 94111-1L	M640777	_____
Antennas			
RE02 Antenna (DRG, 200M-2G)	3106 S/N 2562	M651458	_____
RE02 Antenna (DRG, 200M-2G)	3106 S/N 2729	1963110	_____
RE02 Antenna (DRG, 1-18G)	3115 S/N 5631	M642380	_____
RE02 Antenna (DRG, 1-18G)	3115 S/N 4230	M651306	_____
RE02 Antenna (DRG, 1-18G)	3115 S/N 27001	M651068	_____
RE02 Antenna (DRG, 1-18G)	3115 S/N 27016	M651067	_____
RE102 BCE Clamps			
RE102 BCE Absorbing Clamp	FCC F-201-23mm S/N 130	M653760	_____
RE102 BCE Absorbing Clamp	FCC F-201-23mm	S/N 87	_____
Pre-amplifiers			
Pre-Amplifier	R&S TS-PR18 (SN 001)	2131486	_____
Pre-Amplifier	R&S TS-PR18 (SN 002)	2131485	_____
Pre-Amplifier	R&S TS-PR18 (SN100017)	1667072	_____
EMI Receivers/Spectrum Analyzers			
EMI Test Receiver	R/S ES126 S/N 001	2015727	_____
EMI Test Receiver	R/S ES126 S/N 002	2015728	_____
Spectrum Analyzer	HP 8590L	1535135	_____
Spectrum Analyzer	HP 8591E	1279517	_____

EI24 Electromagnetic Environmental Effects (E3) Team
NASA MSFC EMI Test Facility (METF)
Building 4708, room 1191

Date:_____ Project Name: _____ Sheet 2 of 6

Nomenclature:	**Model**	**Cal ID**	**Cal Due Date**
E-field Sensors			
E-field Sensor (10k-1G)	AR FP5000 S/N 28495	2015540	_____
E-field Sensor (10k-1G)	AR FP5000 S/N 28496	2015541	_____
E-field Sensor (10k-1G)	AR FP5000 S/N 308151	3054635	_____
E-field Sensor (10k-1G)	AR FP5000 S/N 308190	3054636	_____
Isotropic Field Probe (80M-40G)	AR FP2080 S/N300564	2017452	_____
Isotropic Field Probe (80M-40G)	AR FP2080 S/N300467	2017451	_____
Isotropic Field Probe (80M-40G)	AR FP5080 S/N 309517	3054633	_____
Isotropic Field Probe (80M-40G)	AR FP5080 S/N 309520	3054634	_____
Rack mount multimeters			
Digital Multimeter	HP 3455A	676443	_____
Digital Multimeter	HP 3458A	1153180	_____
Digital Multimeter	Agilent 34401A	M648609	_____
Digital Multimeter	Agilent 34401A	M648610	_____
Handheld multimeters/Current probes			
Digital Multimeter (handheld)	Fluke 87	M624653	_____
Digital Multimeter	Fluke 73 III	M648654	_____
Digital Multimeter	Fluke 73 III	M648781	_____
AC/DC Current Probe	Fluke i410	M644165	_____
AC/DC Current Probe	Fluke i410	M647219	_____
Digital Multimeter (handheld)	Fluke 867B	M636809	_____
Digital Multimeter (handheld)	Fluke 867B	M647219	_____

EI24 Electromagnetic Environmental Effects (E3) Team
NASA MSFC EMI Test Facility (METF)
Building 4708, room 1191

Date:_____ Project Name: _____ Sheet 3 of 6

Nomenclature:	**Model**	**Cal ID**	**Cal Due Date**
Oscilloscope and Probe Sets			
Digital Oscilloscope	Tek TDS 640A	1962460	_____
10X 500MHz probe	Tek P6139A	M647225	_____
10X 500MHz probe	Tek P6139A	M650710	_____
10X 500MHz probe	Tek P6139A	M650932	_____
10X 500MHz probe	Tek P6139A	M647224	_____
10X 500MHz probe	Tek P6139A	M653770	_____
Digital Oscilloscope	Tek TDS 350	M651061	_____
10X 200MHz probe	Tek P6111B	M636600	_____
10X 200MHz probe	Tek P6111B	M646347	_____
10X 200MHz probe	Tek P6111B	M636599	_____
10X 200MHz probe	Tek P6111B	M633189	_____
10X 200MHz probe	Tek P6111B	M648138	_____
10X 200MHz probe	Tek P6111B	M629337	_____
Digital Oscilloscope	Tek TDS5104B	3053118	_____
10X 500MHz probe	Tek P5050	M653631	_____
10X 500MHz probe	Tek P5050	M653632	_____
10X 500MHz probe	Tek P5050	M653633	_____
10X 500MHz probe	Tek P5050	M653634	_____
Handheld Scope	Tek THS720A	M651413	_____
10X 200MHz probe	Tek P6117	M653768	_____
10X 200MHz probe	Tek P6117	M653769	_____
Handheld Scope	Tek THS720A	M653273	_____
10X 200MHz probe	Tek P6117	M653275	_____
10X 200MHz probe	Tek P6117	M653767	_____
Handheld Scope	Tek THS730A	M653766	_____
10X 200MHz probe	Tek P6117	M653765	_____
10X 200MHz probe	Tek P6117	M653766	_____

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NASA MSFC EMI Test Facility (METF)
Building 4708, room 1191

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Nomenclature:	**Model**	**Cal ID**	**Cal Due Date**
Microohm Meters			
Microohm Meter	Keithley 580	M651647	_____
Microohm Meter	Keithley 580	1218588	_____
Microohm Meter	Keithley 580	M252213	_____
LISNs			
MIL-STD-461E LISN, 24A	Solar 8028-50-TS-24-BNC	M650555	_____
MIL-STD-461E LISN, 24A	Solar 8028-50-TS-24-BNC	M650556	_____
MIL-STD-461D LISN, 100A	Solar 8116-50-TS-100-N	S/N 972052	_____
MIL-STD-461D LISN, 100A	Solar 8116-50-TS-100-N	S/N 974706	_____
MIL-STD-461D LISN, 200A	Solar 9331-50-TS-200-N	S/N 981917	_____
MIL-STD-461D LISN, 200A	Solar 9331-50-TS-200-N	S/N 981918	_____
Signal Generators			
Synthesizer/ Function Gen	HP 3325B	M651752	_____
Synthesizer/ Function Gen	HP 3325B	1148596	_____
Synthesizer/ Function Gen	HP 33120A	M651908	_____
Synthesizer/ Function Gen	Agilent 33220A	M653773	_____
Synthesizer/ Function Gen	Agilent E8257C	M651402	_____
Synthesizer/ Function Gen	HP 83620B	1895123	_____
Synthesizer/ Function Gen	HP 8341B	G84508	_____
Power Meters			
Power Meter Set #1	Boonton 5232	M651674	_____
Power Sensor Set #1	Boonton 51011-EMC	M650451	_____
Power Sensor Set #1	Boonton 51011-EMC	M650450	_____
RF Probe Set #1	Boonton 952001B	M650453	_____
Power Meter Set #2	Boonton 5232	1965172	_____
Power Sensor Set #2	Boonton 51011-EMC	M649236	_____
Power Sensor Set #2	Boonton 51011-EMC	M649237	_____
RF Probe Set #2	Boonton 952001B	M652298	_____

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Date:_____ **Project Name: _____** **Sheet 5 of 6**

Nomenclature:	**Model**	**Cal ID**	**Cal Due Date**
Differential scope probes			
Differential Probe	Tek P5205 SN: B018399	M649623	_____
Differential Probe	Tek P5205 SN: B018346	M649624	_____
Differential Probe	Tek P5205 SN: B017288	M649436	_____
Differential Probe	Tek P5205 SN: B020810	M652222	_____
Miscellaneous			
High Voltage Attenuator	Solar 9410-1	M650519	_____
High Voltage Attenuator	Solar 9410-1	M650520	_____
Directional Coupler	Werlatone C5086-10	M653772	_____
Directional Coupler	Werlatone C5086	S/N 8111	_____
Directional Coupler	Werlatone C5086	S/N 8112	_____

EI24 Test Conductor : _____ Date : _____

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NASA MSFC EMI Test Facility (METF)
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Date:_____ Project Name: _____ Sheet 6 of 6

Other Test Equipment Utilized:

Nomenclature:	**Model**	**Cal ID**	**Cal Due Date**
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
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_____	_____	_____	_____
_____	_____	_____	_____

EI24 Test Conductor : _____ Date : _____

6. DETAILED REQUIREMENTS

6.1 General.

This section specifies detailed emissions and susceptibility requirements and the associated test procedures. Table VII is a list of the specific requirements established by SL-E-0002 Book 3 Volume 1 identified by requirement number and title. General test procedures are included in this section. Specific test procedures are implemented by the approved customer-prepared EMITP. All results of tests performed to demonstrate compliance with the requirements are to be documented in both the customer-prepared and the METF-prepared EMITR and forwarded to the designated authority for evaluation prior to acceptance of the equipment or subsystem. SL-E-0002 Book 3 Volume 1 states that design procedures and techniques for the control of EMI shall be described in the customer-prepared EMICP. Approval of design procedures and techniques described in the EMICP does not relieve the supplier of the responsibility of meeting the contractual emission, susceptibility, and design requirements.

6.1.1 Units of frequency domain measurements.

All frequency domain limits are expressed in terms of equivalent Root Mean Square (RMS) value of a sine wave as would be indicated by the output of a measurement receiver using peak envelope detection (see 5.3.10.1).

TABLE VII. Emission and susceptibility requirements.

Requirement	Description
CE102	Conducted Emissions, Power Leads, 10 kHz to 10 MHz
CE106	Conducted Emissions, Antenna Terminal, 100MHz to 18GHz
CS101	Conducted Susceptibility, Power Leads, 30 Hz to 150 kHz
CS103	Conducted Susceptibility, Antenna Port, Intermodulation, 15 kHz to 10GHz
CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals, 30Hz to 18GHz
CS105	Conducted Susceptibility, Antenna Port, Cross Modulation, 30 Hz to 18 GHz
CS106	Conducted Susceptibility, Power-Line Switching Transients
CS114	Conducted Susceptibility, Bulk Cable Injection, 10 kHz to 200 MHz
CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10 kHz to 10 MHz
RE102	Radiated Emissions, Electric Field, 150 kHz to 18 GHz
RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs, 100 MHz to 18 GHz
RS103	Radiated Susceptibility, Electric Field, 30MHz to 18GHz
TT101	Conducted Emission, Time Domain, DC Power Leads, Transient and Steady-State

6.2 Tests applicable to this EUT and pass/fail status.

The tests applicable to this EUT are shown in Table VIII. The overall test results are shown in the pass/fail column. The detailed test results are contained in the EUT test run log and the test summary found in Section 1 of the METF test report. The two criteria pass or fail are assigned to emissions testing, where a defined limit line determines whether the EUT passes or fails. The two criteria pass or effects are assigned to susceptibility testing, where the EUT owner must determine whether a particular effect observed during a susceptibility test would affect mission performance or not.

TABLE VIII. EUT Tests performed and test results.

Subtest	Applicable to this EUT	Pass/Fail/Effect
CE102		
CE106		
CS101		
CS103		
CS104		
CS105		
CS106		
CS114		
CS116		
RE102		
RE103		
RS103		
TT101		

6.3 CE102, conducted emissions, power leads, 10 kHz to 10 MHz.

6.3.1 CE102 applicability.

This requirement is applicable from 10 kHz to 10 MHz for all power leads, including returns that obtain power from primary sources.

6.3.2 CE102 limits.

Conducted emissions on power leads shall not exceed the applicable values shown on Figure CE102-1.

6.3.3 CE102 test procedure.

6.3.3.1 Purpose.

This test procedure is used to verify that electromagnetic emissions from the EUT do not exceed the specified requirements for power input leads, including returns.

6.3.3.2 Test equipment.

The test equipment will be as follows:

Table CE102-1. METF CE102 Equipment.

Item	METF Equipment	Calibration ID	Calibration Due Date
Measurement receiver	Rohde&Schwarz ESI measurement receiver, 20Hz-26.5GHz		
Data recording device	Personal computer functioning as data recording device	N/A	N/A
Signal Generator	HP 3325B, HP33220A, HP333120A, or equivalent _____		
Attenuator, 20dB, 50 ohm	Attenuator, 20dB, 50 ohm	N/A	N/A
Oscilloscope	Tektronix THS720A, 100MHz, or equivalent _____		
LISN (Positive Lead)	Solar MIL-STD-461E LISN Model # _____		
LISN (Return Lead)	Solar MIL-STD-461E LISN Model # _____		
Test Software		N/A	N/A

6.3.3.3 Setup.

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 5.3.8.

b. Calibration.

(1) Configure the test setup for the measurement system check as shown in Figure CE102-2. Ensure that the EUT power source is turned off.

(2) Connect the 20 dB attenuator directly to the "EMI meter" port of the LISN.

(3) Connect the measurement receiver to the 20 dB attenuator using the actual coaxial cable that will be used to make the CE102 EUT measurement.

(4) Record any deviation from the standard CE102 setup on CE102 deviation page(s) as needed.

c. EUT testing.

(1) Configure the test setup for compliance testing of the EUT as shown in Figure CE102-3.

(2) Connect the 20dB attenuator directly to the "EMI meter" port of the LISN. Conect the Rhode & Schwarz measurement receiver to the 20 dB attenuator.

(3) Connect the measurement receiver to the 20dB attenuator using the CE102 measurement coaxial cable.

(4) Record any deviation from the standard CE102 setup on CE102 deviation page(s) as needed.

6.3.3.4 Procedures.

The test procedures shall be as follows:

a. Calibration. Perform the measurement system check using the measurement system check setup of Figure CE102-2.

(1) Turn on the measurement equipment and allow a sufficient time for stabilization.

(2) Ensure that the appropriate correction factors for the LISN coupling capacitor, coax cable, and 20 dB attenuator are in the Rhode and Schwarz CE102 scan table

(3) Apply a signal level that is at least 6 dB below the limit at 10 kHz, 100 kHz, 2 MHz and 10 MHz to the power output terminal of the LISN. Ensure signal generator output is in Vrms and is sinusoidal. At 10 kHz and 100 kHz, use an oscilloscope (set up 50 ohm input) to measure the signal level and verify that it is sinusoidal. Ensure oscilloscope input is set to 1X probe. At 2 MHz and 10 MHz, use a calibrated output level directly from a 50 Ω signal generator.

(4) Scan the measurement receiver for each frequency in the same manner as a normal data scan. Pause the EMI receiver control software at appropriate points to enable changing the signal generator frequency and amplitude. Verify that the measurement receiver indicates a level within ±3 dB of the injected level. Correction factors shall be applied for the 20dB attenuator and the voltage drop due to the LISN 0.25 microfarad coupling capacitor.

(5) Record the signal injection level, measured level, and any attenuation used on the signal generator output in the CE102 measurement system spreadsheet on the computer workstation.

(6) If readings are obtained which deviate by more than ±3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.

(7) Repeat steps (2) through (4) above for each LISN.

(8) Record any deviations from the standard CE102 calibration procedure on CE102 deviation page(s) as needed.

b. EUT testing. Perform emission data scans using the measurement setup of Figure CE102-3.

(1) Turn on the EUT and allow a sufficient time for stabilization.

(2) Select an appropriate lead for testing.

(3) Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times in the Table V.

(4) Repeat steps (2) and (3) above for each power lead.

(5) Record any deviations from the standard CE102 EUT test procedure on CE102 deviation page(s) as needed.

6.3.3.5 Data presentation.

Data presentation shall be as follows:

a. Continuously and automatically plot amplitude versus frequency profiles on X-Y axis outputs. Manually gathered data is not acceptable except for plot verification.

b. Display the applicable limit on each plot.

c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.

d. Provide plots for both the measurement system check and measurement portions of the procedure.

e. Record results in the test run log spreadsheet on the METF computer workstation.

6.3.3.6 CE102 Test Procedure/Configuration Notes.

EUT:_____

6.3.3.7 CE102 Test Procedure Deviations.

EUT:_____

The MFOP-FA-EMI-304 CE102 facility operating procedures were followed during the CE102 test with the exception of the following deviations:

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METF Test Conductor signature: _____ Date: _____

EUT Test Conductor signature: _____ Date: _____

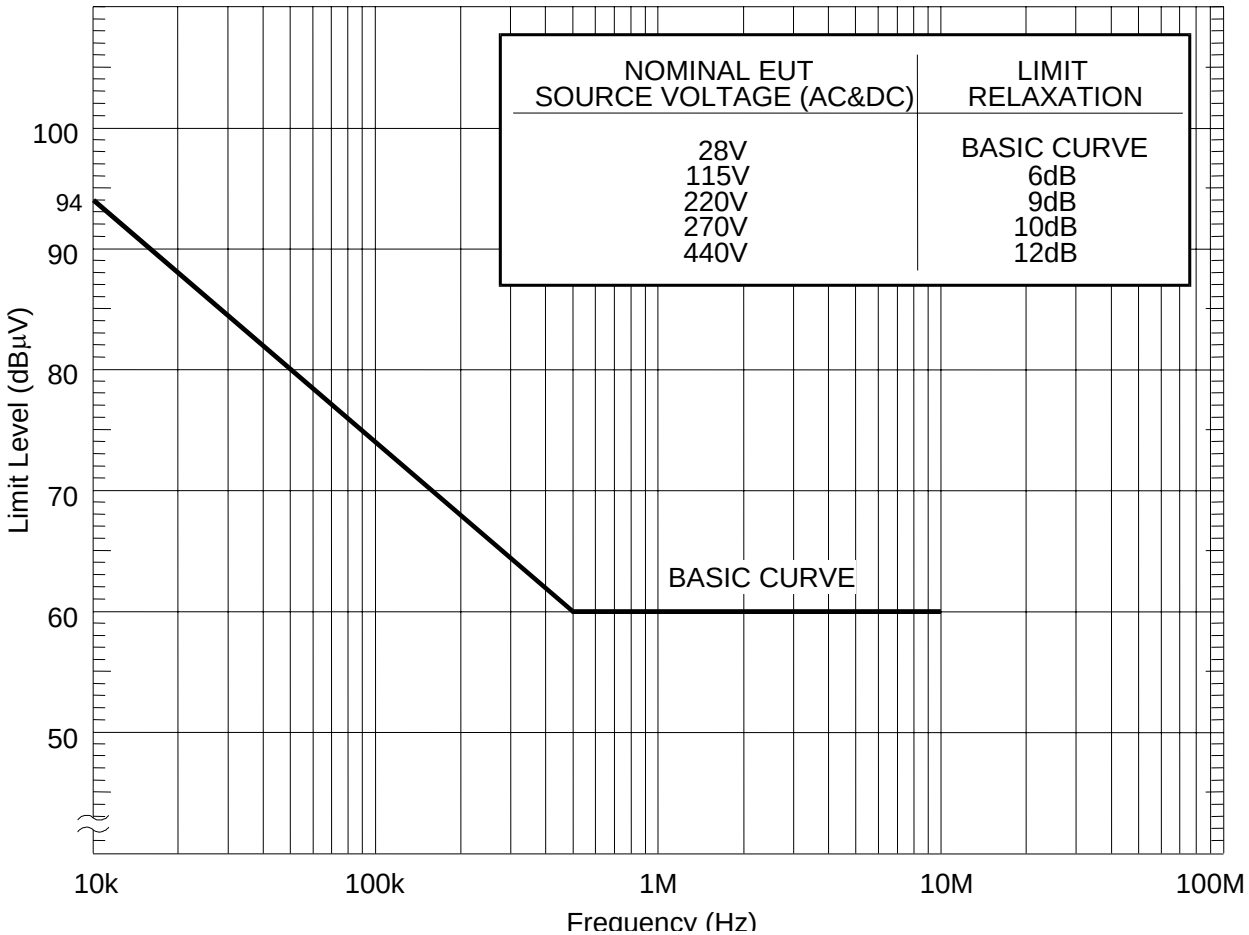

FIGURE CE102-1. CE102 limit (EUT power leads, AC and DC) for all applications.

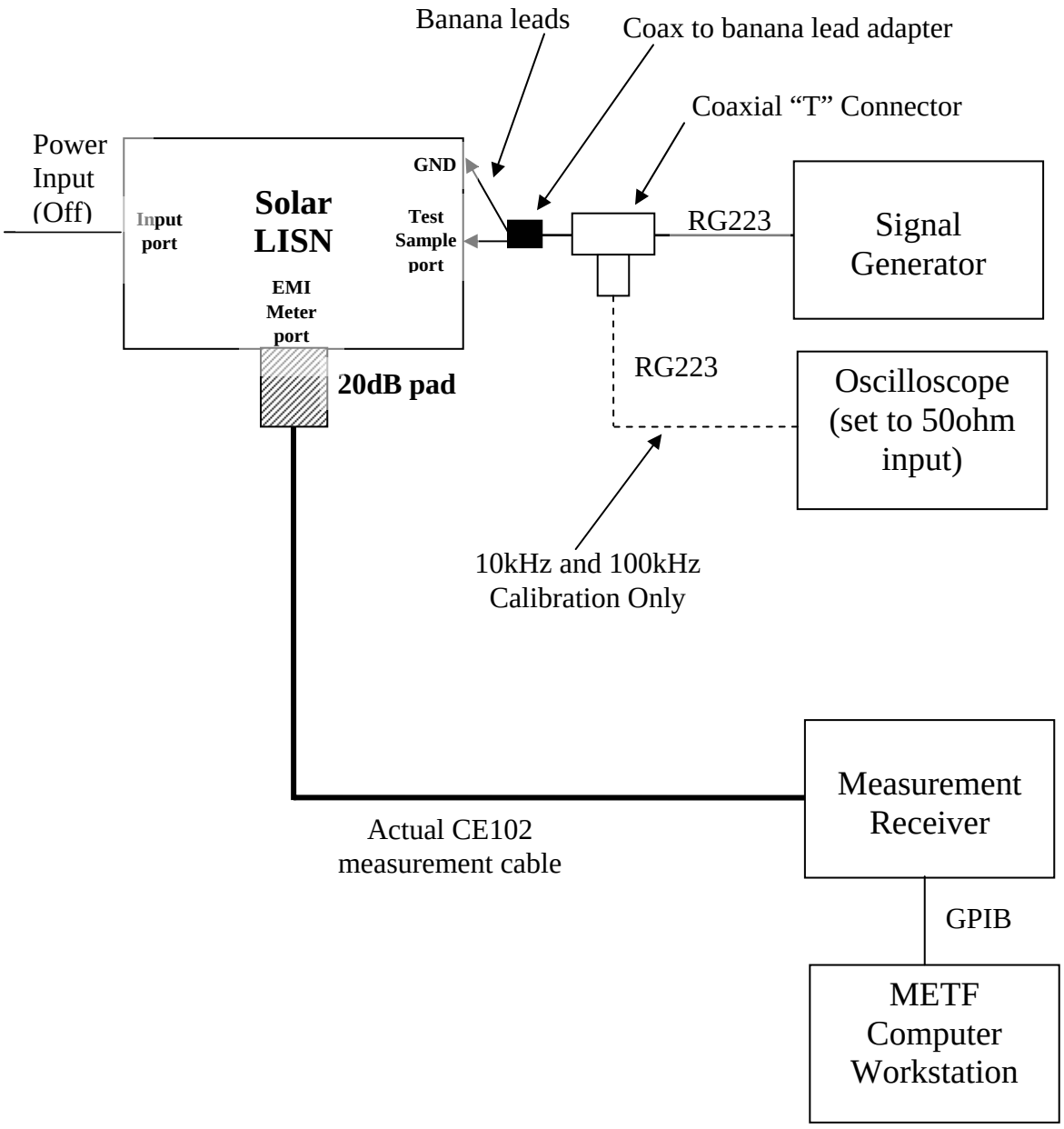

FIGURE CE102-2. Measurement system check setup.

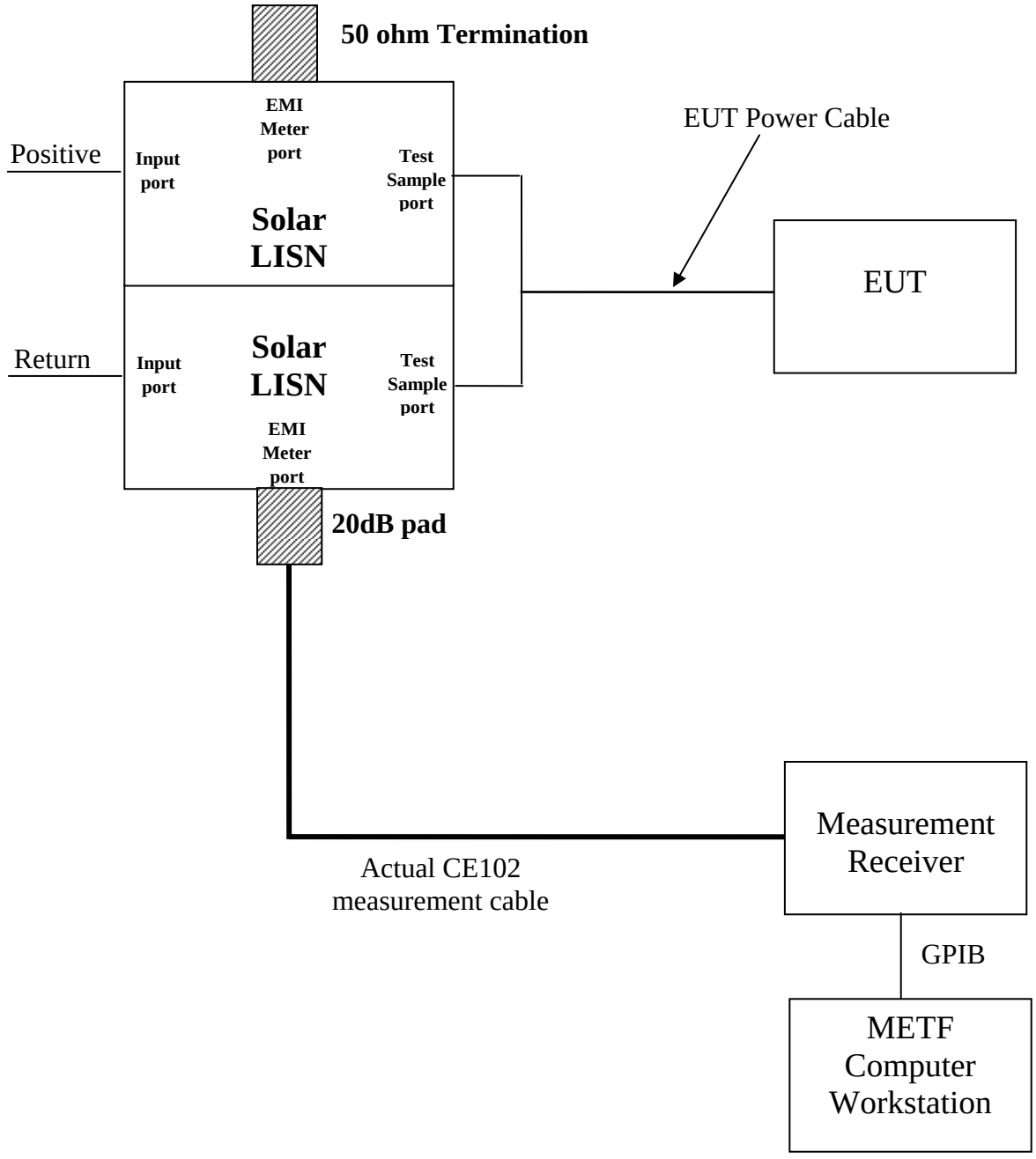

FIGURE CE102-3. Measurement setup.

6.4 CS101, conducted susceptibility, power leads, 30 Hz to 150 kHz.

6.4.1 CS101 applicability.

This requirement is applicable to equipment and subsystem AC and DC input power leads, not including returns. If the EUT is DC operated, this requirement is applicable over the frequency range of 30 Hz to 150 kHz. If the EUT is AC operated, this requirement is applicable starting from the second harmonic of the EUT power frequency and extending to 150 kHz.

6.4.2 CS101 limit.

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to a test signal with voltage levels as specified in Figure CS101-1. The requirement is also met when the power source is adjusted to dissipate the power level shown in Figure CS101-2 in a 0.5 ohm load and the EUT is not susceptible.

Additional CS101 Test – Any EUT meeting all the criteria defined below shall perform an additional susceptibility test to determine whether the equipment performance is adversely affected by the following waveform:

Ripple amplitude of 14 Volts (V) peak-to-peak with a 500-700 Hz sawtooth ripple for a duration of 250 milliseconds.

This waveform is representative of the worst case noise generated on the aft power busses when the hydraulic circulation pumps are powered on. Test of EUT response to such ripple levels shall follow the CS101 test techniques defined below. When the EUT fails to function within performance, the ripple amplitude at which the EUT fails (i.e. susceptibility threshold) shall be determined and the test results submitted to the procuring authority.

Criteria for performing additional CS101 test:

a. The EUT is classified as EMC critical equipment.

b. The EUT operates from an aft cargo bay 28 VDC power bus.

c. The EUT has a non-redundant power interface to a single power bus.

d. The EUT is operated on-orbit.

6.4.3 CS101 test procedure.

6.4.3.1 Purpose.

This test procedure is used to verify the ability of the EUT to withstand signals coupled onto input power leads.

6.4.3.2 Test equipment.

The test equipment will be as follows:

Table CS101-1. METF CS101 Equipment.

Item	METF Equipment	Calibration ID	Calibration Due Date
Signal generator	HP3325B, 30Hz-20MHz, or equivalent _____		
Power amplifier	Techron 752 power amplifier, 20Hz-25kHz, 144W, or equivalent _____	N/A	N/A
Oscilloscope	Tektronix THS720A, 100MHz, or equivalent _____		
Coupling transformer	Solar Type 6220-1A coupling transformer, 30Hz-250kHz, 50A dc	N/A	N/A
Capacitor, 10uF	Capacitor, 10uF	N/A	N/A
Resistor, 0.5 ohm	Dale RH-250 250W resistor, 0.5 ohm (2 1 ohm resistors in parallel) or equivalent	N/A	N/A
LISN (Positive Lead)	Solar MIL-STD-461E LISN Model # _____		
LISN (Return Lead)	Solar MIL-STD-461E LISN Model # _____		
Test Software		N/A	N/A
Voltmeter	HP3458A digital multimeter, or equivalent _____		
Video monitoring camera	EMC Automation VC-04 video camera, controller, and monitor or equivalent	N/A	N/A

6.4.3.3 Setup.

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 5.3.8.

b. Calibration. Configure the test equipment in accordance with Figure CS101-3. Set up the oscilloscope, voltmeter and test software to monitor the voltage across the 0.5 ohm resistor.

c. Trial run on calibration resistor. Configure the test equipment in accordance with Figure CS101-3. Set up the oscilloscope, voltmeter, and test software to monitor the voltage across the 0.5 ohm resistor.

d. EUT testing.

(1) For DC or single phase AC power, configure the test equipment as shown in Figure CS101-4.

(2) For three phase ungrounded power, configure the test setup as shown in Figure CS101-5.

(3) For three phase wye power (four power leads), configure the test setup as shown in Figure CS101-6.

e. Record any deviations from the CS101 calibration or EUT test setup on CS101 deviation sheet(s) as needed.

6.4.3.4 Procedures.

The test procedures shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.

b. Calibration.

(1) Configure the EMI test software to set the signal generator to the lowest test frequency.

(2) Increase the applied signal until the oscilloscope and the digital multimeter indicate the voltage level corresponding to the maximum required power level specified for the limit. Verify the output waveform is sinusoidal on the oscilloscope.

(3) The test software will record the setting of the signal source for this power level.

(4) Scan the required frequency range for testing and record the signal source setting needed to maintain the required power level in Figure CS101-2.

c. Trial run on calibration resistor to confirm test setup is correct, applied voltage level is correct, and waveform is sinusoidal.

(1) Configure the test software for a CS101 run with the same parameters as for an EUT run (amplitude, frequency step size, etc.)

(2) Perform a CS101 run on the calibration resistor. Closely monitor the oscilloscope screen, using the remote control camera, to ensure the correct voltage is applied at each frequency and that the waveform is sinusoidal.

(3) If the oscilloscope does not agree with the test software output, stop and determine the source of the problem. Correct the problem before continuing to EUT testing.

d. EUT Testing.

(1) Turn on the EUT and allow sufficient time for stabilization.

(2) Configure the test software to set the signal generator to the lowest test frequency. Increase the signal level until the required voltage or power level is reached on the power lead. Note: Power is limited to the level calibrated in step b, Item 2 (above).

(3) While maintaining at least the required signal level, scan through the required frequency range at a rate no greater than specified in Table V.

(4) Closely monitor the oscilloscope screen, using the remote control camera, to ensure that the CS101 voltage limit is not exceeded. If the voltage is exceeded at any frequency, immediately stop the test software and determine the source of the problem.

(5) Susceptibility evaluation.

(a) Monitor the EUT for degradation of performance.

(b) If susceptibility is noted, determine the threshold level in accordance with 5.3.10.4.3 and verify that it is above the limit.

(5) Repeat steps 2 through 5 above for each power lead, as required. For three phase ungrounded power, the measurements shall be made according to the following table:

Coupling Transformer in Line	Voltage Measurement From
A	A to B
B	B to C
C	C to A

For three phase wye power (four leads) the measurements shall be made according to the following table:

Coupling Transformer in Line	Voltage Measurement From
A	A to neutral
B	B to neutral
C	C to neutral

6.4.3.5. Data presentation.

Data presentation shall be as follows:

a. Record results in the test run log spreadsheet on the METF computer workstation.
b. Provide graphical or tabular data showing the frequencies and amplitude from the calibration run.
c. Provide graphical or tabular data showing the frequencies and amplitudes at which the test was conducted for each lead.
d. Provide data on any susceptibility thresholds and the associated frequencies that were determined for each power lead.
e. Provide indications of compliance with the applicable requirements for the susceptibility evaluation specified in 5.3.3.4c for each lead.
f. Record any deviations from the standard CS101 calibration or EUT test procedures on CS101 deviation sheet(s) as needed.

6.4.3.6 CS101 Test Procedure/Configuration Notes

EUT:_____

6.4.3.7 CS101 Test Procedure Deviations

EUT:_____

The MFOP-FA-EMI-304 CS101 facility operating procedures were followed during the CS101 test with the exception of the following deviations:

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METF Test Conductor signature: _____ Date: _____

EUT Test Conductor signature: _____ Date: _____

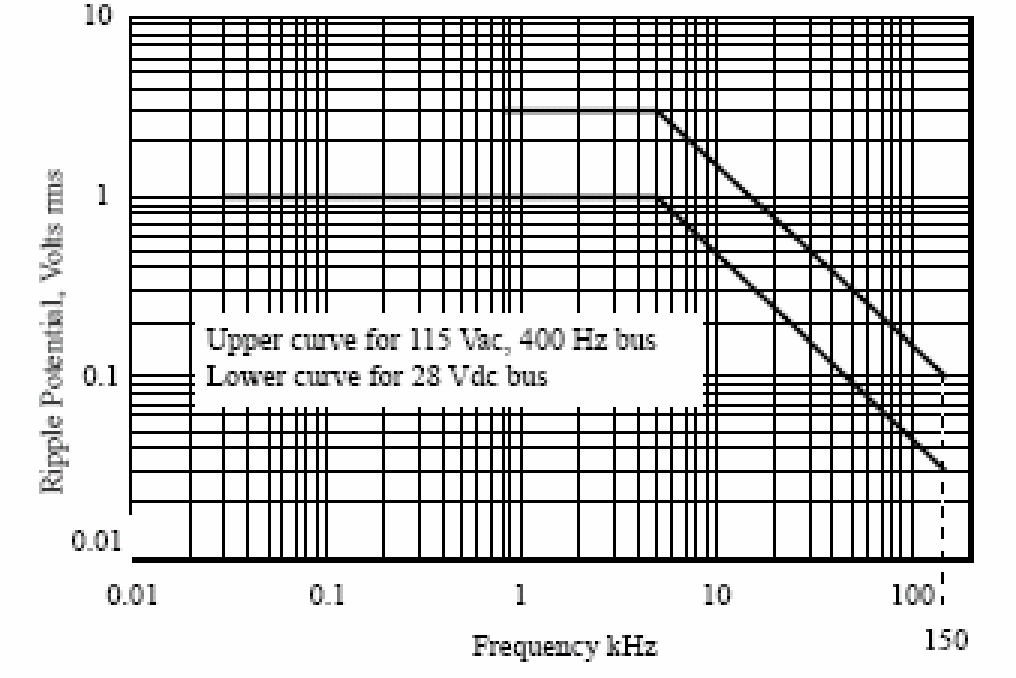

FIGURE CS101-1. CS101 voltage limit for DC and AC Primary Power Buses

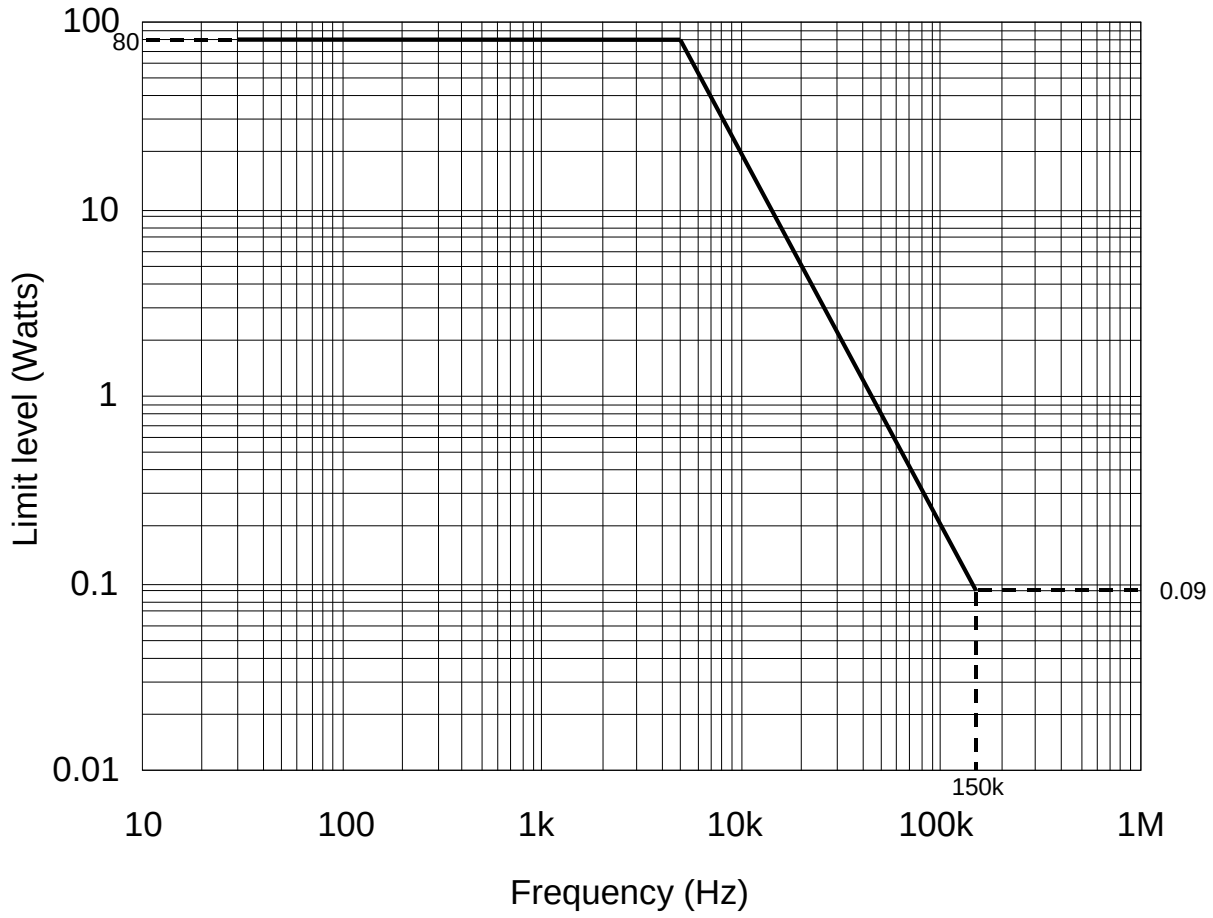

FIGURE CS101-2. CS101 power limit for all applications.

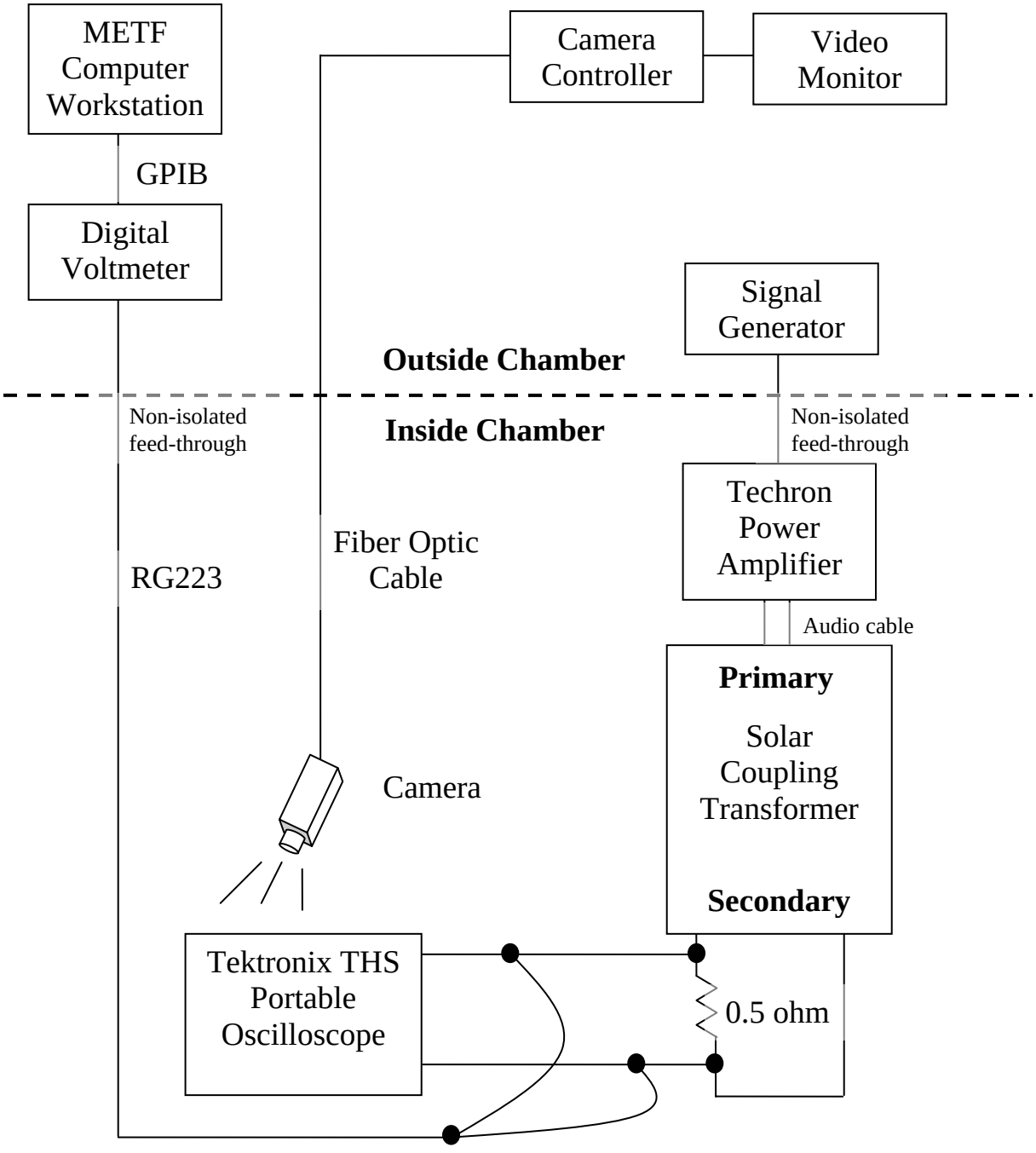

FIGURE CS101-3. Calibration.

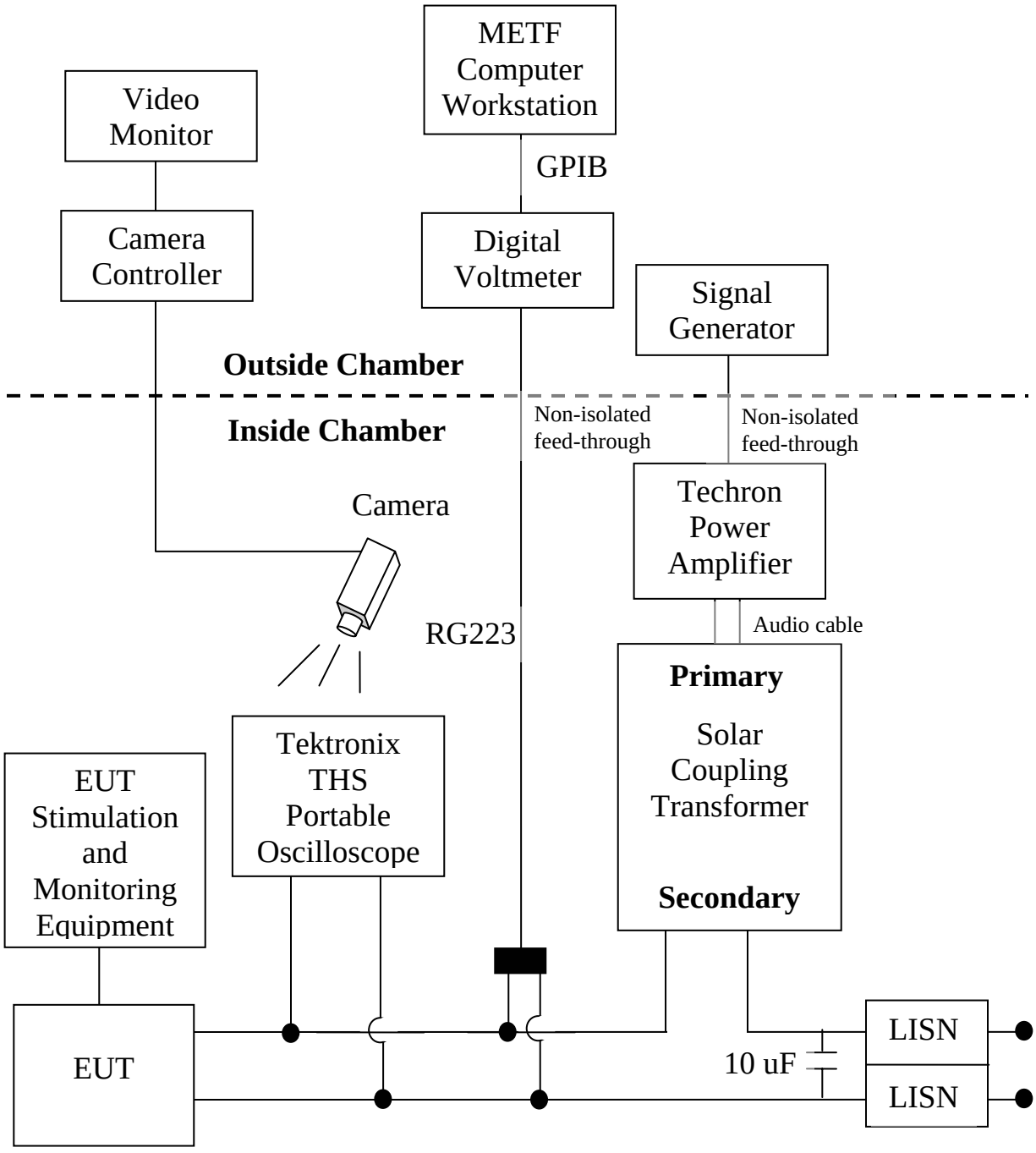

FIGURE CS101-4. Signal injection, DC or single phase AC.

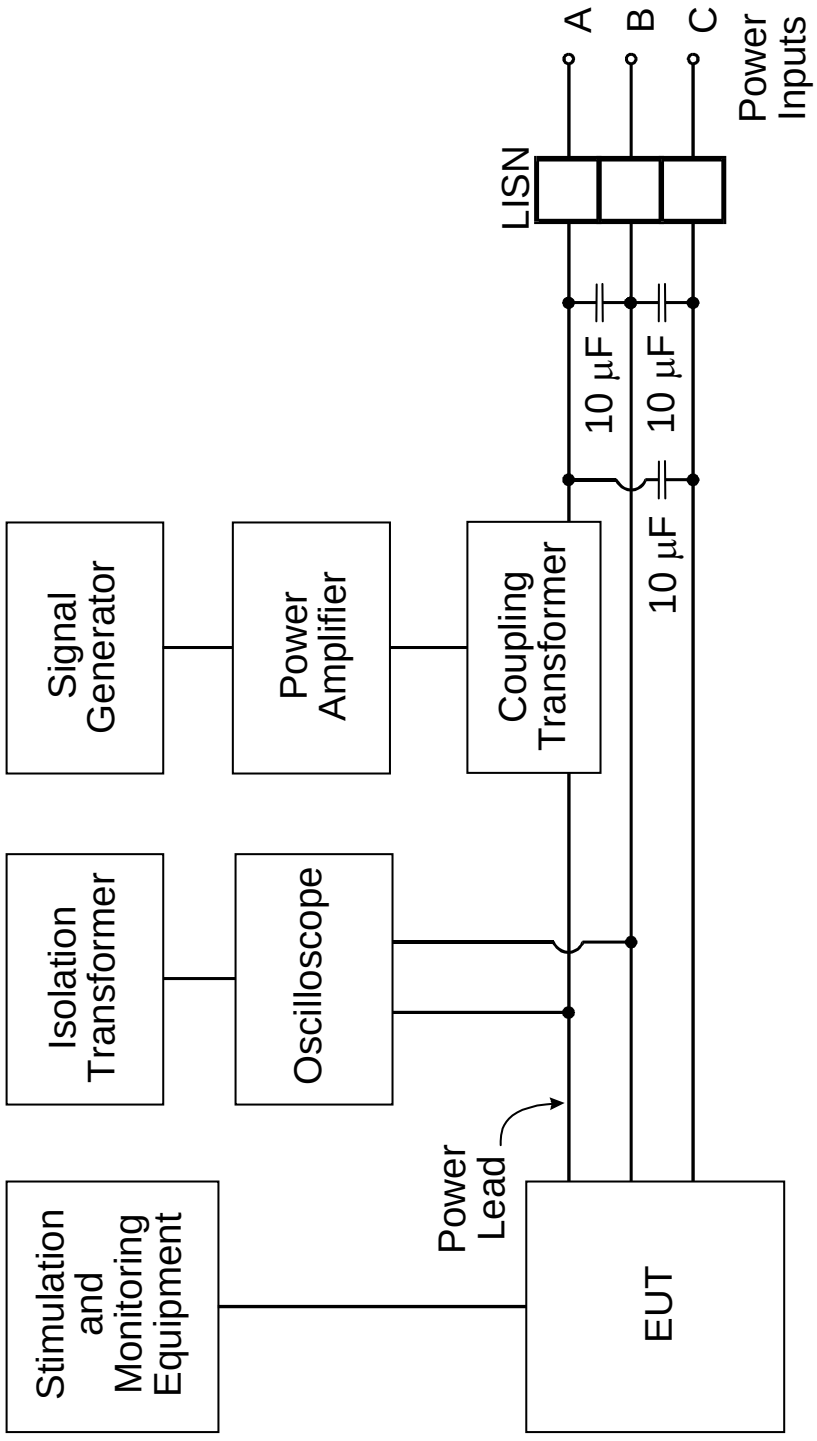

FIGURE CS101-5. Signal injection, 3-phase ungrounded.

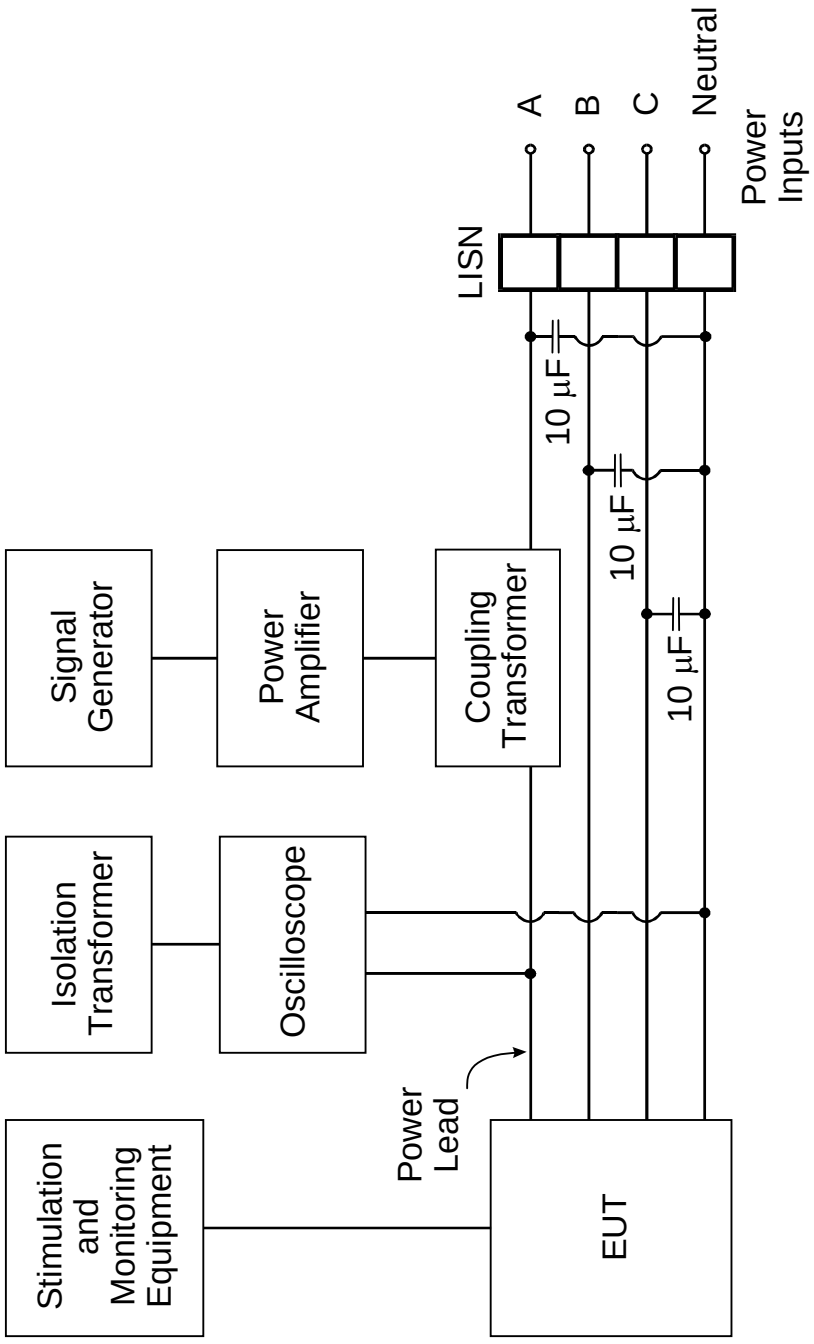

FIGURE CS101-6. Signal injection, 3-phase wye.

6.5 CS114, conducted susceptibility, bulk cable injection, 10 kHz to 200 MHz.

6.5.1 CS114 applicability.

This requirement is applicable to all interconnecting cables, including power cables.

6.5.2 CS114 limit.

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to a injection probe drive level which has been pre-calibrated to the appropriate current limit shown in Figure CS114-1 and is modulated as specified below. Requirements are also met if the EUT is not susceptible at forward power levels sensed by the coupler that are below those determined during calibration provided that the actual current induced in the cable under test is 6 dB or greater than the calibration limit.

6.5.3 CS114 test procedures.

6.5.3.1 Purpose.

This test procedure is used to verify the ability of the EUT to withstand RF signals coupled onto EUT associated cabling.

6.5.3.2 Test equipment.

The test equipment is listed in Table CS114-1.

Table CS114-1. METF CS114 Equipment.

Item	METF Equipment	Calibration ID	Calibration Due Date
Measurement Receiver A	HP8590L Spectrum Analyzer or equivalent		
Measurement Receiver B	Boonton Model 5232 RF Power Meter/Voltmeter		
Current Injector Probe	FCC Model F-120-98 10 kHz – 230 MHz	N/A	N/A
Current Monitor Probe < 10 MHz	Solar Type 6741–1, 100 KHz – 100 MHz		
Current Monitor Probe > 10 MHz	Solar Type 9123-1N, 10kHz-500MHz		
Calibration Fixture, 50Ω	EMCO Model 95241-1 10 KHz – 450 MHz	N/A	N/A

Item	METF Equipment	Calibration ID	Calibration Due Date
Directional Coupler	Werlatone Model C5086 10 KHz – 250 MHz	N/A	N/A
Signal Generator < 10 MHz	HP3325B, Agilent 33120A, Agilent 33220A, or equivalent, 10kHz-10MHz		
Signal Generator >10 MHz	HP83620B, Agilent E8257C, or equivalent 10 MHz – 20 GHz		
Attenuators, 50 Ω, DC to 1 GHz	Various	N/A	N/A
Coaxial Load, 50 Ω	Solar Type 9841-1	N/A	N/A
Power Amplifier	Ophir Model 5084	N/A	N/A
LISN (Positive Lead)	Solar MIL-STD-461E LISN Model # _____		
LISN (Return Lead)	Solar MIL-STD-461E LISN Model # _____		
Laptop Computer	Dell	N/A	N/A
Test Software		N/A	N/A

6.5.3.3 Setup.

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 5.3.8.

b. Calibration. Configure the test equipment in accordance with Figure CS114-3 for calibrating injection probes.

(1) Place the injection probe around the center conductor of the calibration fixture.

(2) Terminate one end of the calibration fixture with a 50 ohm load and terminate the other end with an attenuator connected to measurement receiver A.

c. EUT Testing. Configure the test equipment as shown in Figure CS114-4 for testing of the EUT.

(1) Place the injection and monitor probes around a cable bundle interfacing with an EUT connector.

(2) Locate the monitor probe 5 cm from the connector. If the overall length of the connector and backshell exceeds 5 cm, position the monitor probe as close to the connector's backshell as possible.

(3) Position the injection probe 5 cm from the monitor probe.

6.5.3.4 Procedures.

The test procedures shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.

b. Calibration. Perform the following procedures using the calibration setup. Note that the test software performs each of these steps.

(1) Set the signal generator to 10 kHz, unmodulated.

(2) Increase the applied signal until measurement receiver A indicates the current level specified in the applicable limit is flowing in the center conductor of the calibration fixture.

(3) Record the "forward power" to the injection probe indicated on measurement receiver B.

(4) Scan the frequency band from 10 kHz to 200 MHz and record the forward power needed to maintain the required current amplitude.

c. EUT Testing. Perform the following procedures on each cable bundle interfacing with each electrical connector on the EUT including complete power cables (high sides and returns). Also perform the procedures on power cables with the power returns and chassis grounds (green wires) excluded from the cable bundle. For connectors which include both interconnecting leads and power, perform the procedures on the entire bundle, on the power leads (including returns and grounds) grouped separately, and on the power leads grouped with the returns and grounds removed.

(1) Turn on the EUT and allow sufficient time for stabilization.

(2) Susceptibility evaluation. Steps (a) through (e) are performed by the test software.

(a) Set the signal generator to 10 kHz with 1 kHz pulse modulation, 50% duty cycle.

(b) Apply the forward power level determined under step b, Item 4 above to the injection probe while monitoring the induced current.

(c) Scan the required frequency range in accordance with 5.3.10.4.1 and Table VI while maintaining the forward power level at the calibration level determined under step b, Item 4 above, or the maximum current level for the applicable limit curve from Figure CS114-1 +6dB, whichever is less stringent. The amplifier gain may have to be increased at some frequencies to obtain the calibration power limit during EUT testing. The attenuator on the amplifier output may have to be removed at some frequencies to obtain the calibration power limit. These two variables do not impact the validity of the power calibration levels.

(d) Monitor the EUT for degradation of performance during testing.

(e) Whenever susceptibility is noted, determine the threshold level in accordance with 5.3.10.4.3 and verify that it is above the applicable requirement.

(f) For EUTs with redundant cabling for safety critical reasons such as multiple data buses, use simultaneous multi-cable injection techniques.

6.5.3.5 Data presentation.

Data presentation shall be as follows:

a. Provide amplitude versus frequency plots for the forward power levels required to obtain the calibration level as determined in 6.5.3.4b.

b. Complete the test run log on the METF computer workstation showing scanned frequency ranges and statements of compliance with the requirements for the susceptibility evaluation of 6.5.3.4c(2) for each interface connector. Provide any susceptibility thresholds that were determined, along with their associated frequencies.

6.5.3.6 CS114 Test Procedure/Configuration Notes

EUT:_____

6.5.3.7 CS114 Test Procedure Deviations

EUT:_____

The MFOP-FA-EMI-304 CS114 facility operating procedures were followed during the CS114 test with the exception of the following deviations:

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METF Test Conductor signature: _____ Date: _____

EUT Test Conductor signature: _____ Date: _____

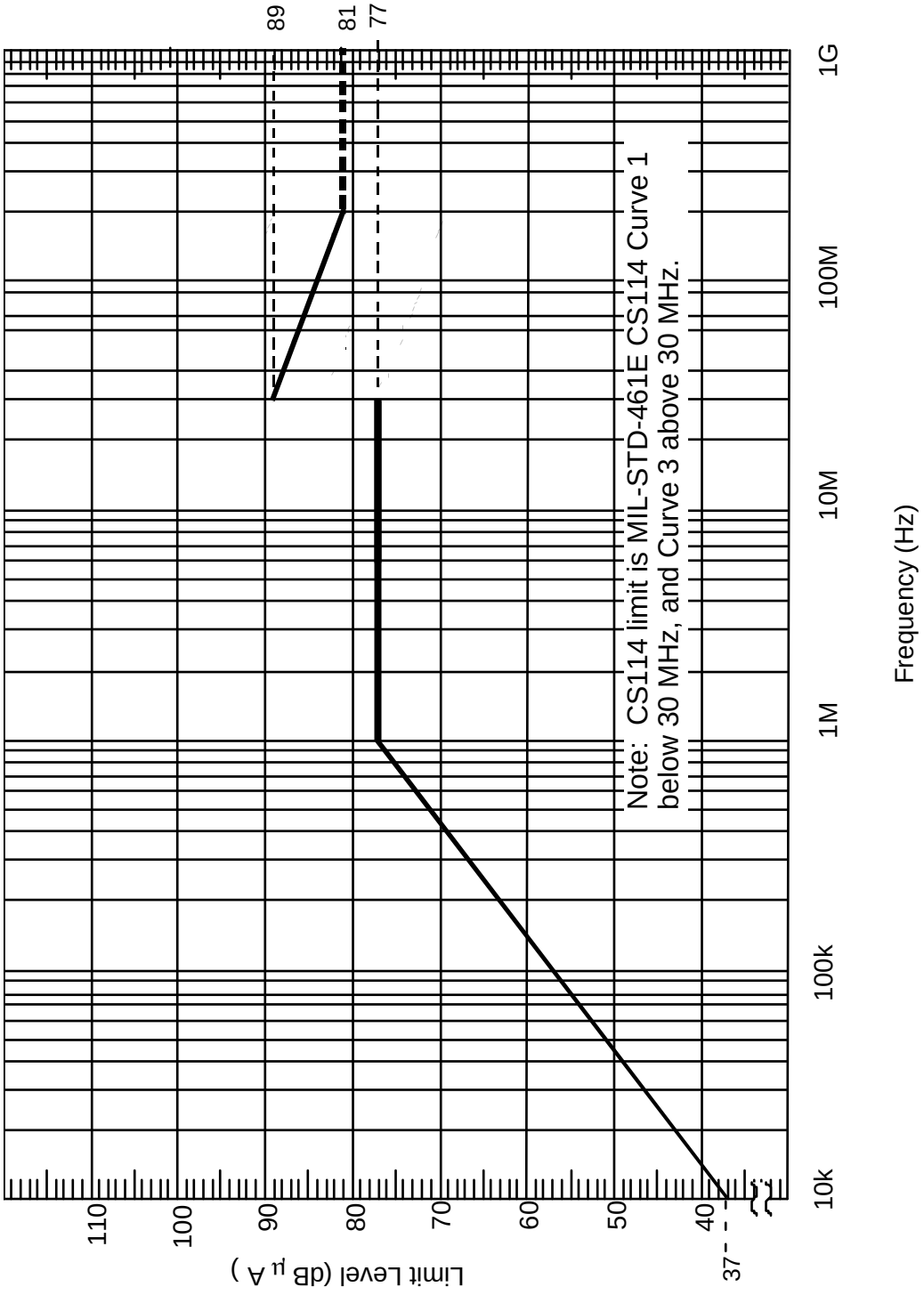

FIGURE CS114-1. CS114 calibration limit for all applications.

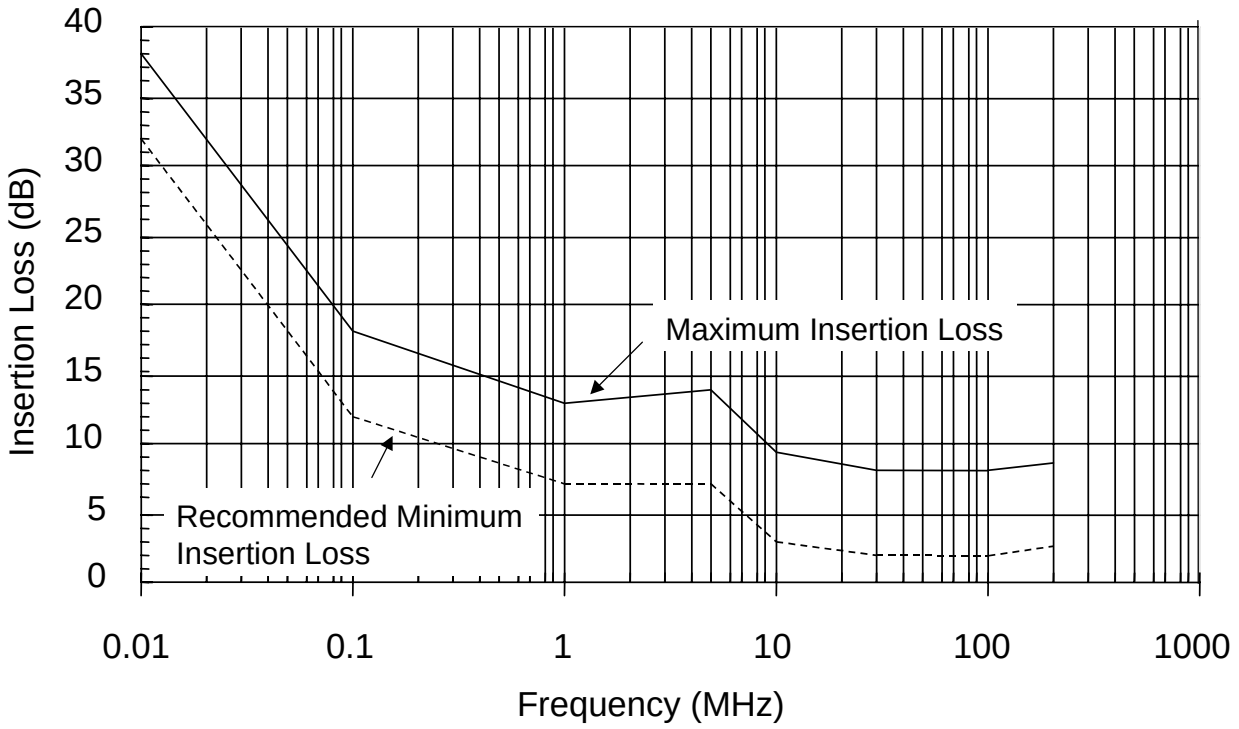

FIGURE CS114-2. Maximum insertion loss for injection probes.

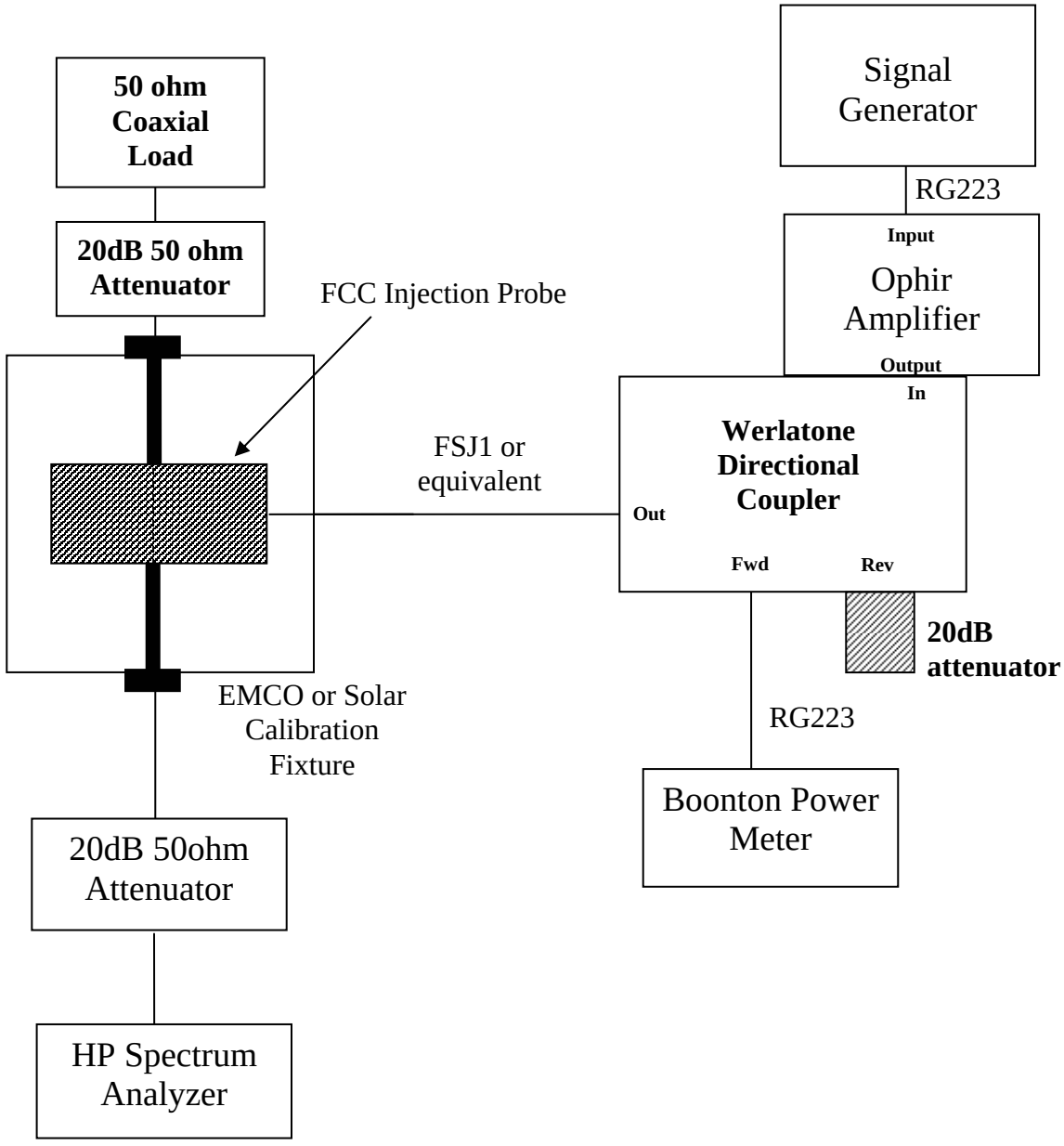

FIGURE CS114-3. Calibration setup.

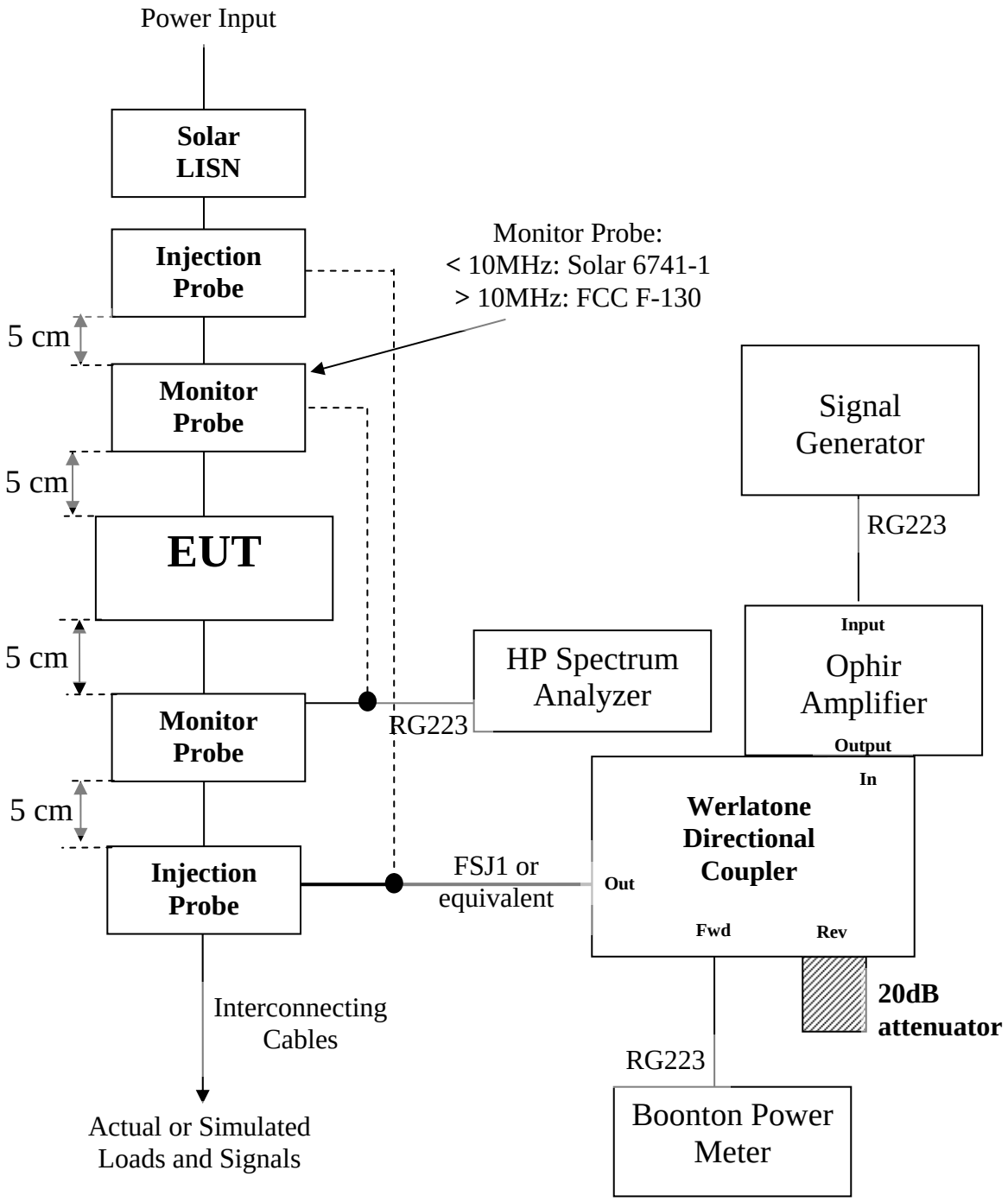

FIGURE CS114-4. Bulk cable injection evaluation.

6.6 CS116, conducted susceptibility, damped sinusoidal transients, cables and power leads, 10 kHz to 100 MHz.

6.6.1 CS116 applicability.

This requirement is applicable to all interconnecting cables, including power cables, and individual high side power leads. Power returns and neutrals need not be tested individually.

6.6.2 CS116 limit.

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to a signal having the waveform shown in Figure CS116-1 and having a maximum current as specified in Figure CS116-2. The limit is applicable across the entire specified frequency range. As a minimum, compliance shall be demonstrated at the following frequencies: 0.01, 0.1, 1, 10 MHz. If there are other frequencies known to be critical to the equipment installation, such as platform resonance, compliance shall also be demonstrated at those frequencies. The test signal repetition rate shall be no greater than one pulse per second and no less than one pulse every two seconds. The pulses shall be applied for a period of five minutes.

6.6.3 CS116 test procedures.

6.6.3.1 Purpose.

This test procedure is used to verify the ability of the EUT to withstand damped sinusoidal transients coupled onto EUT associated cables and power leads.

6.6.3.2 Test equipment.

The test equipment will be as follows:

Table CS116-1. METF CS116 Equipment.

Item	METF Equipment	Calibration ID	Calibration Due Date
Damped sinusoid transient generator, < 100ohm output impedance	Solar Model 9354-1		
Current injection probe	Solar Type 9335-2 current injection probe, 10kHz-10MHz		
Current injection probe	Solar 9142-1N current injection probe, 2MHz-500MHz		

Item	METF Equipment	Calibration ID	Calibration Due Date
Oscilloscope, 50 ohm input impedance	Tektronix TDS640A oscilloscope, 500MHz, or equivalent _____		
Calibration fixture: coaxial transmission line with 50 ohm characteristic impedance, coaxial connections on both ends, and space for an injection probe around the center conductor	Solar Type 9357-1 calibration fixture, 20Hz-100MHz		
Calibration fixture: coaxial transmission line with 50 ohm characteristic impedance, coaxial connections on both ends, and space for an injection probe around the center conductor	Solar Type 9125-1 calibration fixture, 20Hz-500MHz		
Current probe	Solar Type 9123-1N current probe, 10kHz-500MHz		
Current probe	Solar Type 6741-1 current probe, 10kHz-100MHz		
Waveform recording device	HP business inkjet 2280 printer, or equivalent	N/A	N/A
Attenuators, 50 ohm	Solar Model 9410-1 40dB attenuators, 2 each	N/A	N/A
Coaxial loads, 50 ohm	Solar Model 9841-1		
Injection cable	6 foot RG223 50 ohm injection cable		

Item	METF Equipment	Calibration ID	Calibration Due Date
Measurement cable	6 foot RG223 50 ohm measurement cable		
LISN (Positive Lead)	Solar MIL-STD-461E LISN Model # _____		
LISN (Return Lead)	Solar MIL-STD-461E LISN Model # _____		

6.6.3.3. Setup.

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and 5.3.8.

b. Calibration. Configure the test equipment in accordance with Figure CS116-3 for verification of the waveform. Note that the resistor divider network of shown in Figure CS116-5 must be used to reduce the pulse generator output to the levels required by SL-E-0002.

c. EUT Testing:

(1) Configure the test equipment as shown in Figure CS116-4. Note that the resistor divider network shown in Figure CS116-5 must be used to reduce the pulse generator output to the levels required by SL-E-0002.

(2) Place the injection and monitor probes around a cable bundle interfacing with an EUT connector.

(3) Locate the monitor probe 5 cm from the connector. If the overall length of the connector and backshell exceeds 5 cm, position the monitor probe as close to the connector's backshell as possible.

(4) Position the injection probe 5 cm from the monitor probe.

6.6.3.4 Procedures.

The test procedures shall be as follows:

a. Turn on the measurement equipment and allow sufficient time for stabilization.

b. Calibration. Perform the following procedures using the calibration setup for waveform verification.

(1) Set the frequency of the damped sine generator at 10 kHz.

(2) Adjust the amplitude of the signal from the damped sine generator to the level specified in the requirement.

(3) Record the damped sine generator settings in Table CS116-1.

(4) Note: For the 10 KHz waveform, the 9354-1 discharge reference voltage will be very low. When the correct voltage is reached on the oscilloscope, mark the 9354-1 amplitude dial setting with tape on the 9354-1 face. The marked amplitude is the maximum allowed amplitude setting for the EUT testing.

(5) Verify that the waveform complies with the requirements. Calculate Q and enter in Table CS116-1.

(5) Repeat steps 2 through 4 above for each frequency specified in the requirement and those identified in 6.6.3.4c(2). **Ensure that pulse generator is set to the correct waveform for each run.**

c. EUT testing. Perform the following procedures, using the EUT test setup on each cable bundle interfacing with each connector on the EUT including complete power cables. Also perform tests on each individual high side power lead (individual power returns and neutrals are not required to be tested).

(1) Turn on the EUT and measurement equipment to allow sufficient time for stabilization.

(2) From Solar 9123-1N calibration sheet, calculate probe transfer impedance by:

(a) At 10 KHz, read probe correction factor (CF) in dB from the probe cal sheet.

(b) $Z_T = 10^{\frac{-CF}{20}}$

(c) Obtain Z_T at 10 KHz, 100 KHz, 1 MHz, and 10 MHz and enter in Table CS116-2.

(3) Set the damped sine generator to a test frequency.

(4) Apply the test signals to each cable or power lead of the EUT sequentially. Slowly increase the damped sine wave generator output level to provide the specified current, but not exceeding the precalibrated generator output level. Record the peak current obtained. Peak current = peak scope voltage / Z_T at waveform frequency.

(4) Monitor the EUT for degradation of performance.

(5) If susceptibility is noted, determine the threshold level in accordance with 5.3.10.4.3 and verify that it is above the specified requirements.

(6) Repeat steps 2 through 5 above for each test frequency as specified in the requirement. **Repeat testing in step c above (EUT testing) for the power-off condition.**

6.6.3.5. Data presentation.

Data presentation shall be as follows:

a. Provide a list of the frequencies and amplitudes at which the test was conducted for each cable and lead in Table CS116-2 and the test run log on the METF computer workstation.

b. Provide data on any susceptibility thresholds and the associated frequencies that were determined for each connector and power lead in Table CS116-2 and the test run log on the METF computer workstation.

c. Provide indications of compliance with the requirements for the susceptibility evaluation specified in 6.7.3.4c for each interface connector in both Table CS116-2 and the test run log on the METF computer workstation.

d. Provide oscilloscope photographs of injected waveforms with test data.

e. Provide current monitor probe calibration sheets.

6.6.3.6 CS116 Test Procedure/Configuration Notes

EUT:_____

6.6.3.7 CS116 Test Procedure Deviations

EUT:_____

The MFOP-FA-EMI-304 CS116 facility operating procedures were followed during the CS116 test with the exception of the following deviations:

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METF Test Conductor signature: _____ Date: _____

EUT Test Conductor signature: _____Date: _____

EUT:_____ Date:_____

I_{MAX} = 0.5 Amperes

Run/Print	Frequency (Hz)	I_P (mA)	V_P into 50 Ω load (mV)[1]	V_{PS} on scope with 40 dB attenuator (mV)[2]	Use voltage divider	9335-2 port	Calculated Q	9354-1 setting	Scope Settings	
									V/div	Sec/div
	10k	5	250	2.5	Yes	1			1 mV	50 μsec
	100k	50	2500	25	Yes	1			10 mV	5μsec
	1M	500	25000	250	Yes	4			100mV	500 nsec
	10M	500	25000	250	No	4			100mV	50 nsec

Notes:

1. $V_P = I_P * 50$
2. $V_{PS} = V_P / 100$

Table CS116-1. CS116 Calibration Data.

EUT: _____

Cable Under Test: _____

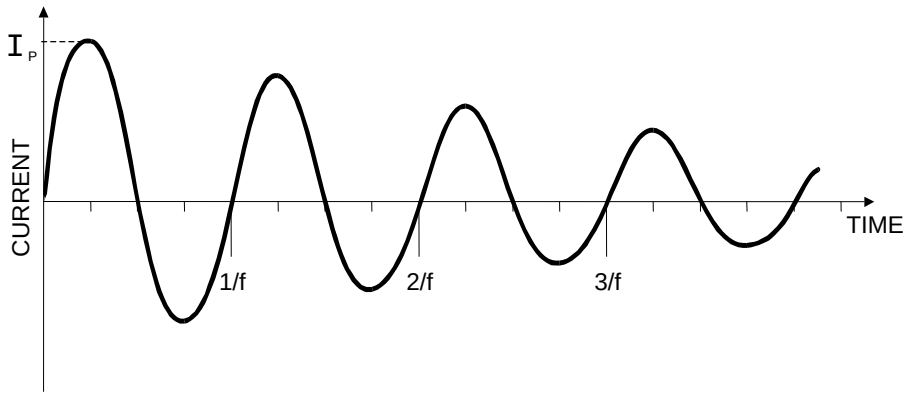
Date: _____

Run / Plot Numbers	CS116 Waveform Frequency (Hz)	CS116 I_P Requirement (mA)	9354-1 discharge reference voltage	9354-1 power limited (Y/N)	Measured V_P (V)	Probe Z_T (Ω)	Measured I_P[1] (mA)	Pass / Effect
	10k	5						
	100k	50						
	1M	500						
	10M	500						

Notes:

1. $I_P = V_P / Z_T$

Table CS116-2. CS116 Test Result



NOTES: 1. Normalized waveform: $e^{-(\pi f t)/Q} \sin(2\pi ft)$

Where:
f = Frequency (Hz)
t = Time (sec)
Q = Damping factor, 15 ± 5

2. Damping factor (Q) shall be determined as follows:

$$Q = \frac{\pi(N - 1)}{\ln(I_P/I_N)}$$

Where:
Q = Damping factor
N = Cycle number (i.e. N = 2, 3, 4, 5,…)
I_P = Peak current at 1st cycle
I_N = Peak current at cycle closest to 50% decay
ln = Natural log

3. I_P as specified in Figure CS116-2

FIGURE CS116-1. Typical CS116 damped sinusoidal waveform.

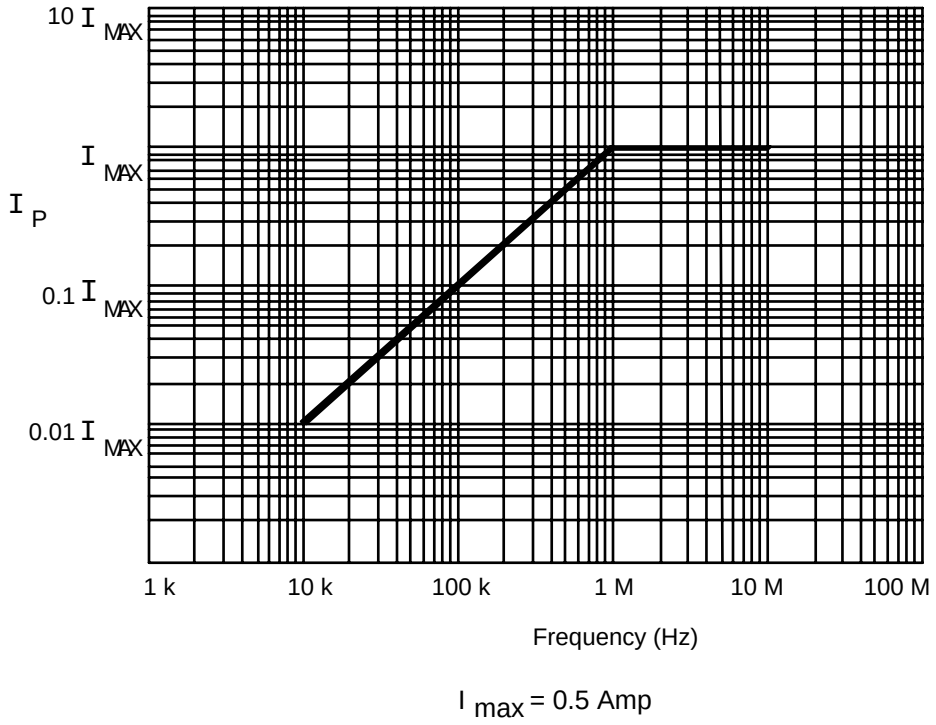


FIGURE CS116-2. CS116 limit for all applications.

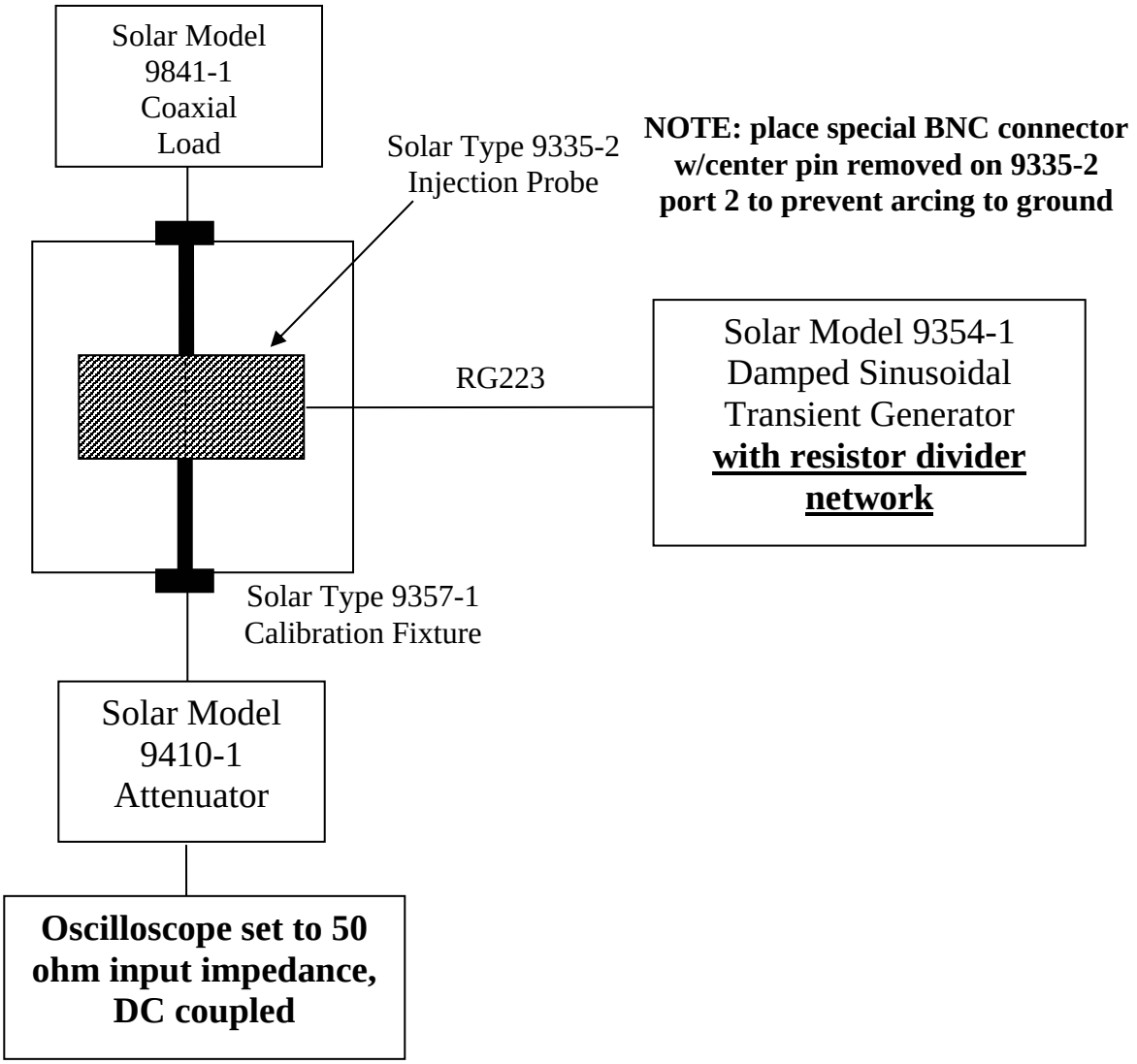


FIGURE CS116-3. Typical test setup for calibration of test waveform

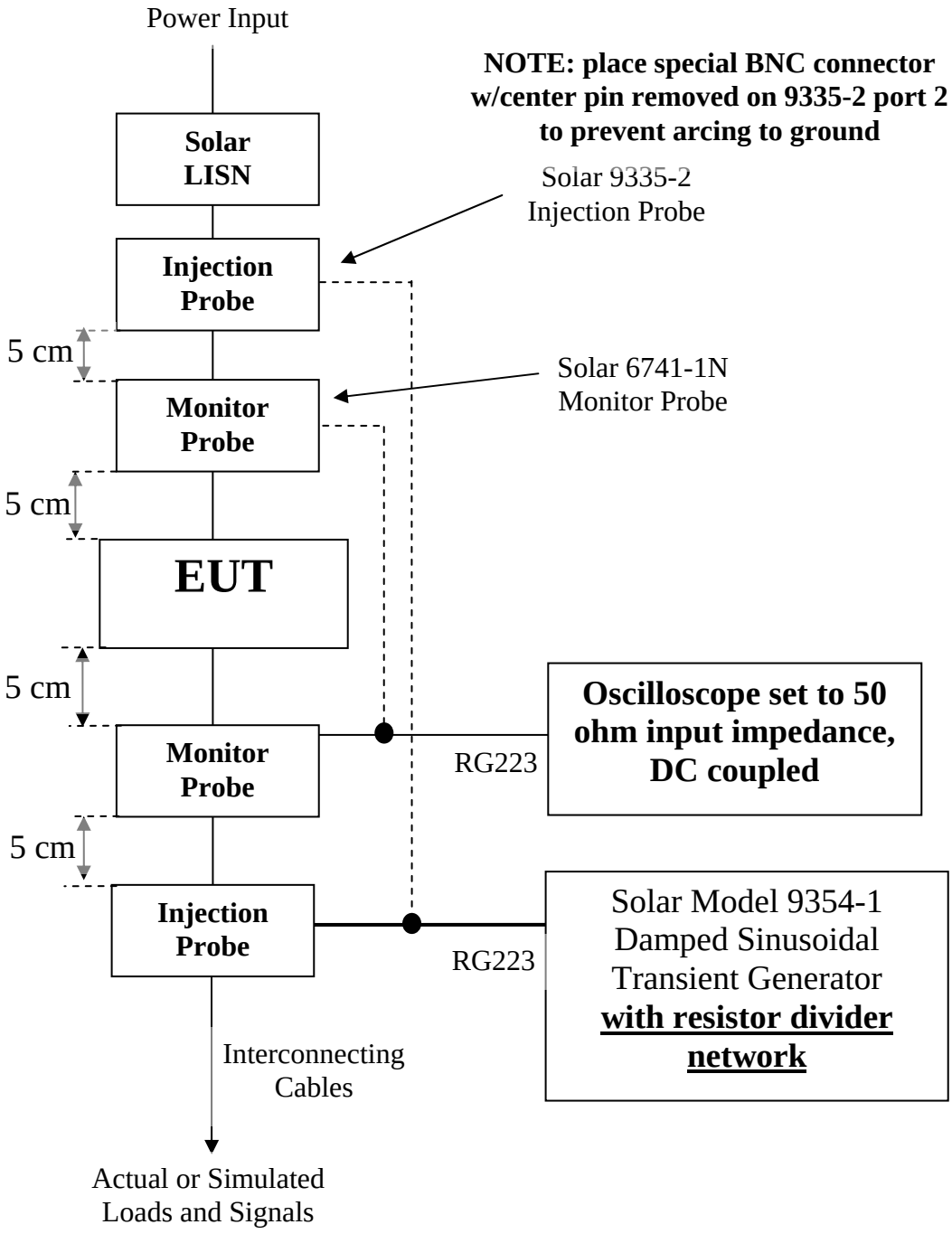


FIGURE CS116-4. Typical set up for bulk cable injection of damped sinusoidal transients.

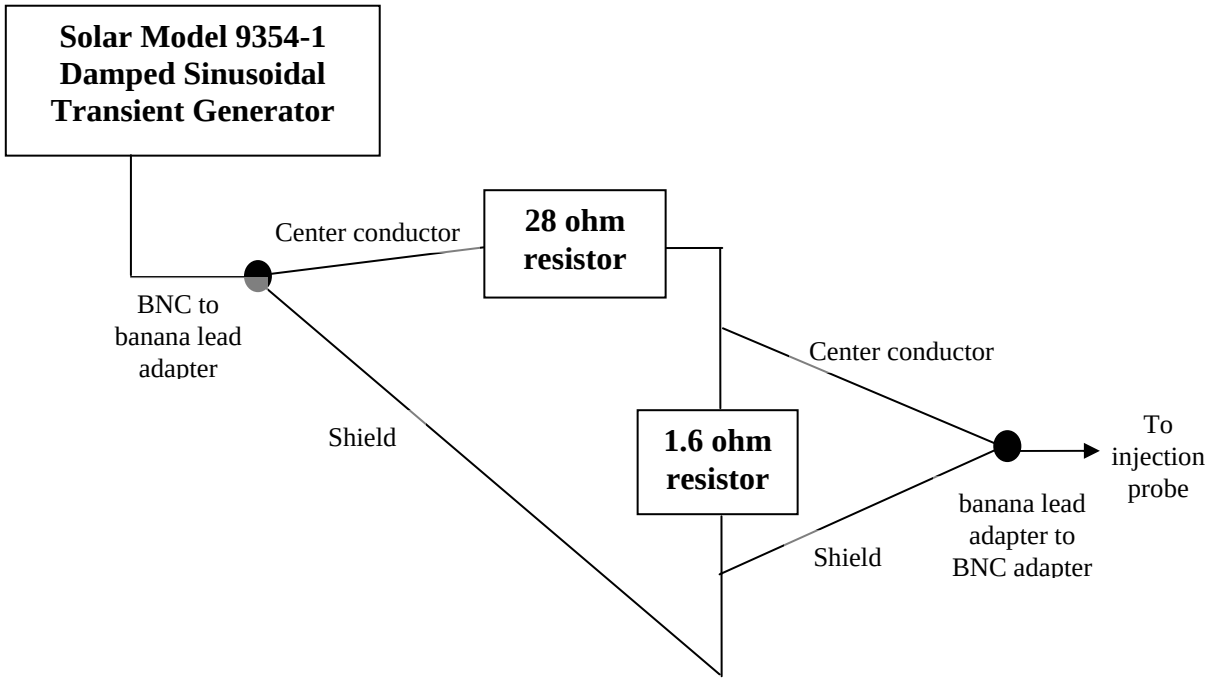


FIGURE CS116-5. Resistor divider network for CS116 testing.

6.7 RE102, radiated emissions, electric field, 150 kHz to 18 GHz.

6.7.1 RE102 applicability.

This requirement is applicable for radiated emissions from equipment and subsystem enclosures, all interconnecting cables, and antennas designed to be permanently mounted to EUTs (receivers and transmitters in standby mode). The requirement does not apply at the transmitter fundamental frequencies. The requirement is applicable as follows:

a. Space Shuttle BCE 150 kHz to 200 MHz

b. Space Shuttle (Including GSE) REs 200 MHz to 18 GHz*

*Testing is required up to 1 GHz or 10 times the highest intentionally generated frequency within the EUT, whichever is greater. Measurements beyond 18 GHz are not required.

6.7.2 RE102 limits.

Electric field emissions shall not be radiated in excess of those shown in Figures RE102-1 through RE102-4. Above 200 MHz, the limits shall be met for both horizontally and vertically polarized fields, when the receive antenna is polarized. Circularly polarized antennas are also acceptable. For Space Shuttle applications, the RE102 limits of Figure RE102-1 through Figure RE102-3 are applicable as defined above 200 MHz as specified in the following sections. The RE limit below 200 MHz is defined by Figure RE102-4 for all applications.

6.7.2.1 Internal Equipment Installation Limits

Equipment located internal to the SSV shall meet the limit depicted in Figure RE102-1.

Equipment that meets all of the following criteria my use the limit depicted in Figure RE102-2.

a. The equipment is located internal to the SSV.

b. The equipment is designated as Criticality 3 or non-critical allowing it to be turned off if interference arises from its operation.

c. The equipment is not operated on the flight deck during launch and entry operational phases.

d. The equipment is not permanently manifested.

6.7.2.2 External Equipment Installation Limits

Equipment installed external to the SSV shall meet the limit depicted in Figure RE102-3 (reference definition in paragraph 3.1).

6.7.3 RE102 test procedures.

6.7.3.1 Purpose.

This test procedure is used to verify that electric field emissions from the EUT and its associated cabling do not exceed specified requirements. The BCE portion of the requirement for Space Shuttle protects against cable-to-cable crosstalk out of band to Shuttle radio receivers.

6.7.3.2 Test Equipment.

The test equipment will be as follows:

Table RE102-1. METF RE102 Equipment.

Item	METF Equipment	Calibration ID	Calibration Due Date
Measurement receiver	Rohde&Schwarz ESI measurement receiver, 20Hz-26.5GHz		
Data recording device	Personal computer functioning as data recording device	N/A	N/A
Test Software		N/A	N/A
Double ridge horn (200MHz-1GHz), 69.0cmx94.5cm opening	EMCO Model 3106 or equivalent		
Double ridge horn (1GHz-18GHz), 24.2cmx13.6cm opening	EMCO Model 3115 or equivalent		
Preamplifier (30MHz-18GHz)	Rohde&Schwarz Model TS-PR18 or equivalent		
Signal Generator (<15MHz)	HP 33120A, 0.1mHz-15MHz, or equivalent		
Signal Generator (>15MHz)	HP83620B or HP8341B or equivalent		
Capacitor, 10pF	METF 10pF calibration fixture	N/A	N/A
Comb Generator (1MHz-1GHz)	Com-Power CG-501, 1MHz step size	N/A	N/A
Comb Generator (1GHz-18GHz)	Com-Power CGO-5100, 100MHz step size	N/A	N/A

Item	METF Equipment	Calibration ID	Calibration Due Date
LISN (Positive Lead)	Solar MIL-STD-461E LISN Model # _____		
LISN (Return Lead)	Solar MIL-STD-461E LISN Model # _____		
Absorbing Clamp (per CISPR 16, Specification for radio disturbance and immunity measuring apparatus and methods), calibrated as a current probe, not per CISPR 16.	FCC F-201-23mm absorbing clamp, or equivalent		

6.7.3.3 Setup.

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figures 1 through 5 and 5.3.8. Ensure that the EUT is oriented such that the surface that produces the maximum radiated emissions is toward the front edge of the test setup boundary.

b. Calibration. For radiated calibration, configure the test equipment as shown in Figure RE102-5. For BCE testing, configure per Figure RE102-6. Record any deviations from the standard RE102 setup on RE102 deviation page(s) as needed.

c. EUT testing.

(1) Antenna Positioning.

(a) Determine the test setup boundary of the EUT and associated cabling for use in positioning of antennas.

(b) Use the physical reference points on the antennas shown in Figure RE102-8 for measuring heights of the antennas and distances of the antennas from the test setup boundary.

1. Position antennas 1 meter from the front edge of the test setup boundary for all setups.

2. Position antennas 120 cm above the floor ground plane.

3. Ensure that no part of any antenna is closer than 1 meter from the walls and 0.5 meter from the ceiling of the shielded enclosure.

4. For test setups using bench tops, additional positioning requirements for the antenna and distance above the bench ground plane are shown in Figure RE102-8.

5. For free standing setups, electrically bond and mount the 104 cm rod antenna matching network to the floor ground plane without a separate counterpoise.

(2) The number of required antenna positions depends on the size of the test setup boundary and the number of enclosures included in the setup (reference Figure RE102-8).

1. For testing from 200 MHz up to 1 GHz, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

2. For testing at 1 GHz and above, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

(3) Record any deviation from the standard RE102 setup on RE102 deviation page(s) as needed.

6.7.3.4 Procedures.

The test procedures shall be as follows:

a. Verify that the ambient requirements specified in 5.3.4 are met. Take plots of the ambient when required by the referenced paragraph.

b. Turn on the measurement equipment and allow a sufficient time for stabilization.

c. Using the system check path of Figure RE102-5, perform the following evaluation of the overall measurement system from each antenna to the data output device at the highest measurement frequency of the antenna.

(1) Apply a calibrated signal level, which is at least 6 dB below the limit (limit minus antenna factor), to the coaxial cable at the antenna connection point. For the BCE calibration, set signal generator to a potential which will yield a current flow at 6 dB below the limit at 150kHz, 10MHz, and 200MHz.

(2) Scan the measurement receiver in the same manner as a normal data scan. Verify that the data recording device indicates a level within ±3 dB of the injected signal level.

(4) Record the signal injection level, measured level, and any attenuation used on the signal generator output in the RE102 measurement system spreadsheet on the METF computer workstation.

(5) If readings are obtained which deviate by more than ±3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.

(6) Record any deviations from the standard RE102 calibration procedure on RE102 deviation page(s) as needed.

d. Using the measurement path of Figure RE102-5, perform the following evaluation for each antenna to demonstrate that there is electrical continuity through the antenna.

(1) Radiate a signal using the applicable comb generator (1MHz to 18GHz).

(2) Scan the measurement receiver for each applicable frequency range, using the bandwidths and minimum measurement times in Table V. Verify that a received signal of appropriate amplitude is present. Note: This evaluation is intended to provide a coarse indication that the antenna is functioning properly. There is no requirement to accurately measure the signal level. Record the verification results in Table RE102-2.

Table RE102-2. Antenna check results

Frequency (Hz)	Antenna Continuity (Yes/No)
1G (large horn)	
18G (small horn)	

e. Turn on the EUT and allow sufficient time for stabilization.

f. Using the measurement path of Figure RE102-5, determine the radiated emissions from the EUT and its associated cabling. Using the setup of Figure RE102-7, measure common mode emissions on all EUT attached cables (both power and signal). NOTE: both power conductors are tested together to ensure that only common mode power-line CEs are measured.

(1) Scan the measurement receiver for each applicable frequency range, using the bandwidths and minimum measurement times in Table V.

(2) Orient the antennas for both horizontally and vertically polarized fields.

(3) Take measurements for each antenna position determined under 6.7.3.3c(2)(c) above.

g. Record any deviations from the standard RE102 EUT test procedure on RE102 deviation page(s) as needed.

6.7.3.5 Data Presentation.

Data presentation shall be as follows:

a. Continuously and automatically plot amplitude versus frequency profiles. Manually gathered data is not acceptable except for plot verification. Vertical and horizontal data for a particular frequency range shall be presented on separate plots or shall be clearly distinguishable in black or white format for a common plot.

b. Display the applicable limit on each plot.

c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.

d. Provide plots for both the measurement and system check portions of the procedure.

e. Complete Table RE102-3 to verify the electrical continuity of the measurement antennas as determined in 6.7.3.4d.

f. Record results in the test run log spreadsheet on the METF computer workstation.

6.7.3.6 RE102 Test Procedure/Configuration Notes

EUT:_____

6.7.3.7 RE102 Test Procedure Deviations

EUT:_____

The MFOP-FA-EMI-304 RE102 facility operating procedures were followed during the RE102 test with the exception of the following deviations:

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METF Test Conductor signature: _____ Date: _____

EUT Test Conductor signature: _____Date: _____

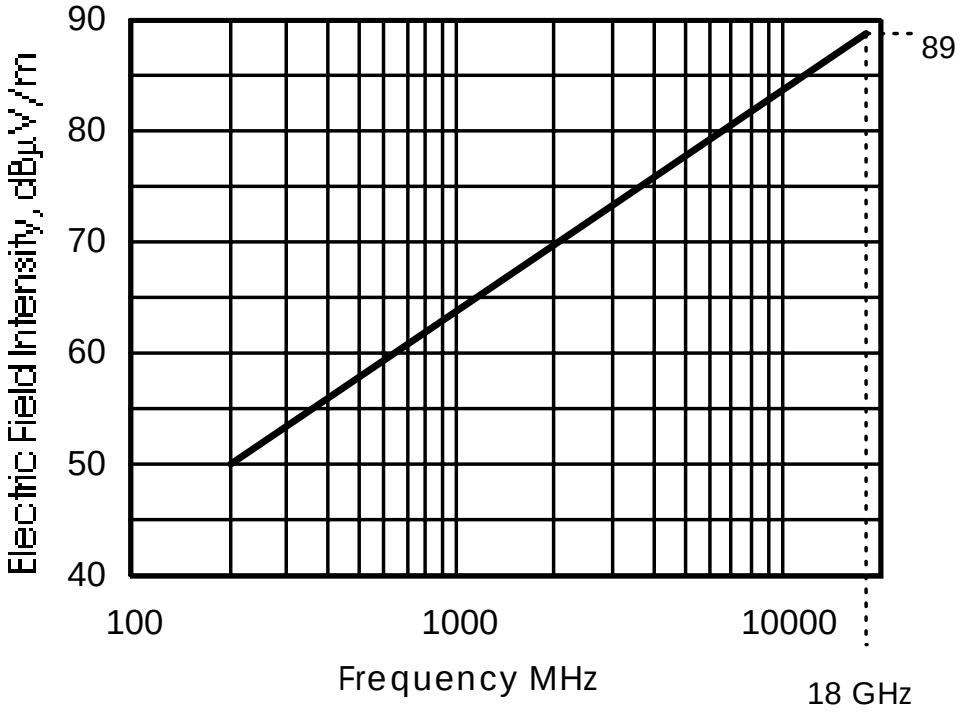

FIGURE RE102-1. RE102 limit for internal equipment.

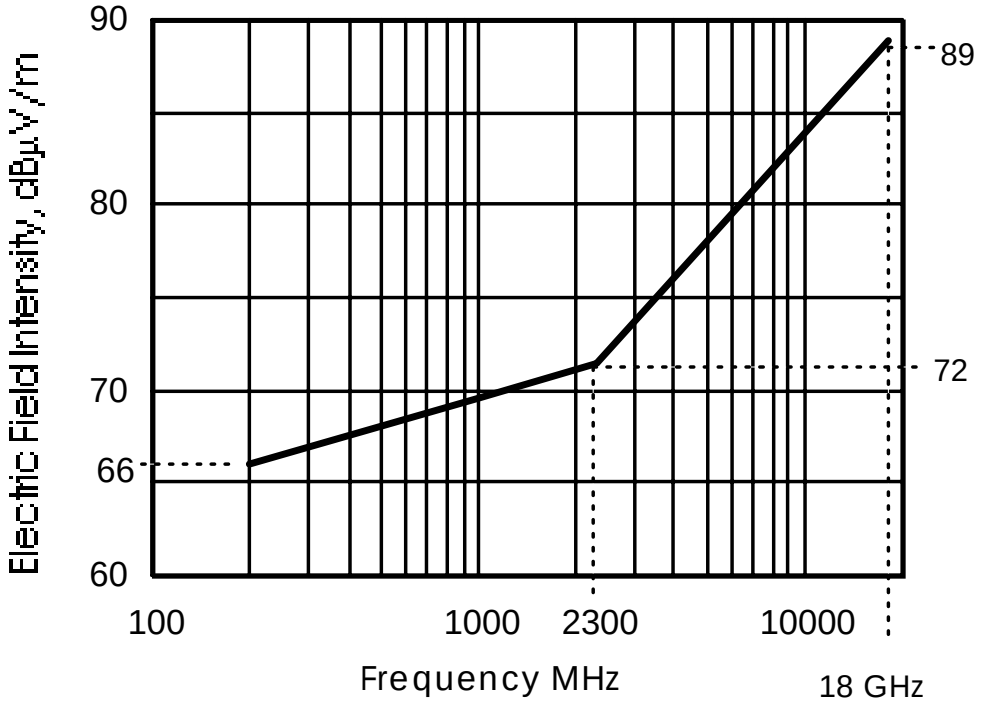

FIGURE RE102-2. RE102 limit for internal equipment that meets all the criteria of section 6.8.2.1.

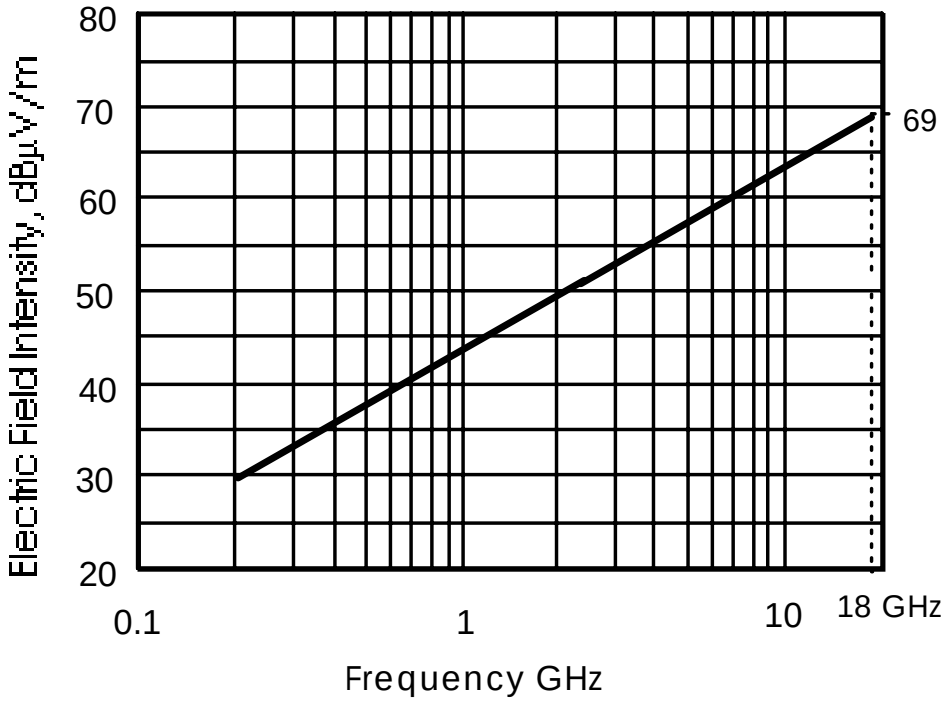

FIGURE RE102-3. RE102 limit for external equipment.

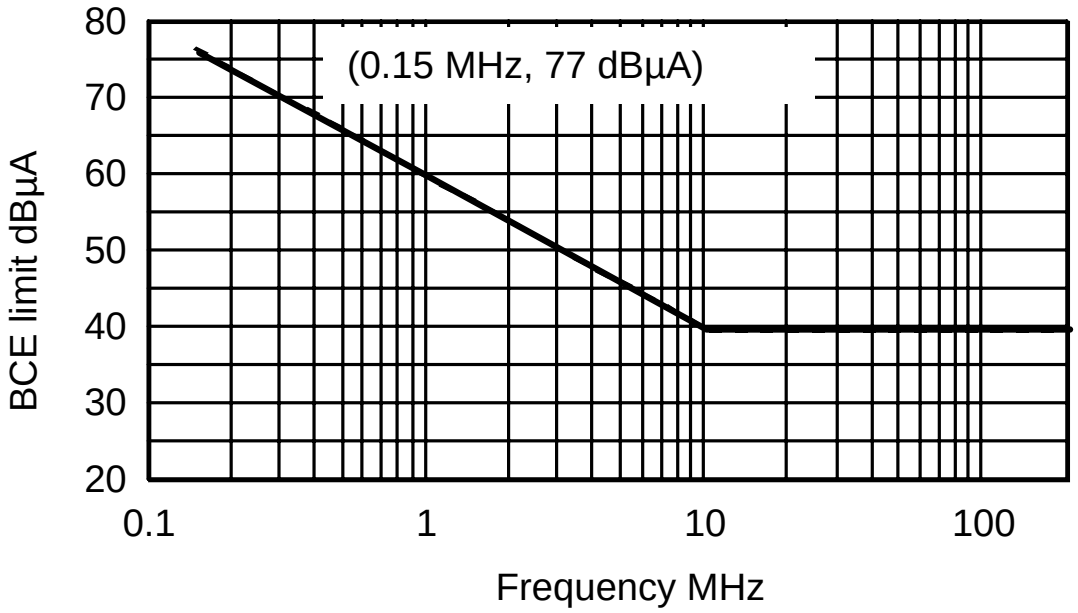

FIGURE RE102-4. BCE limit for Space Shuttle applications.

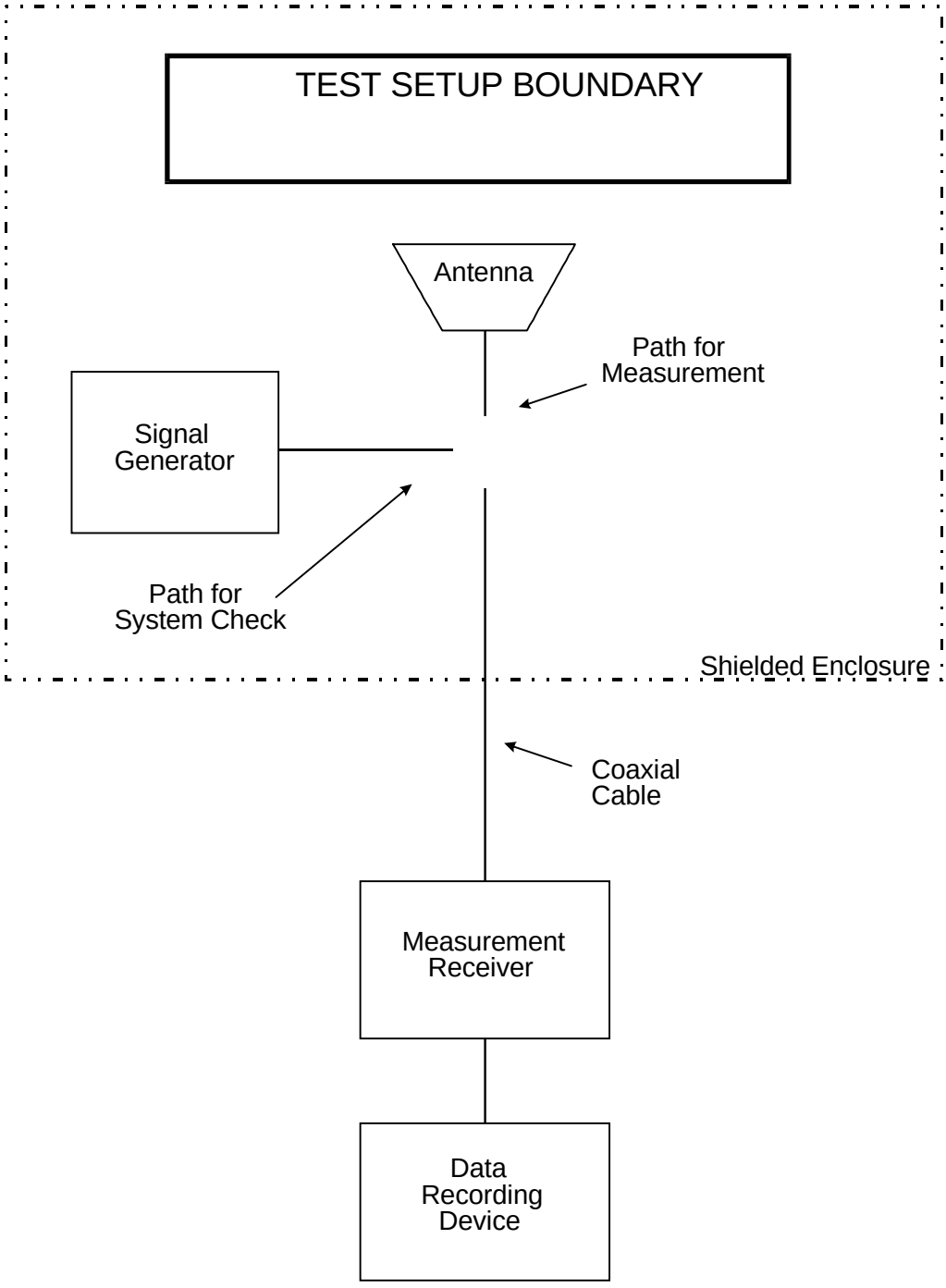

FIGURE RE102-5. Basic test setup.

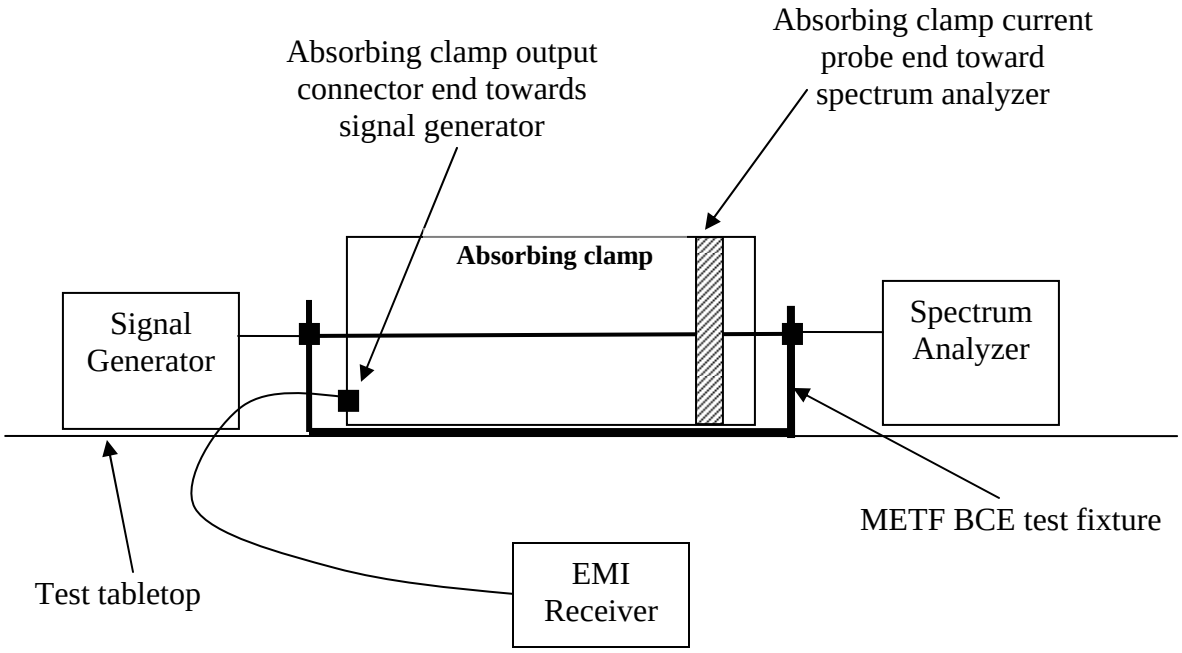

FIGURE RE102-6. Basic BCE measurement system check setup.

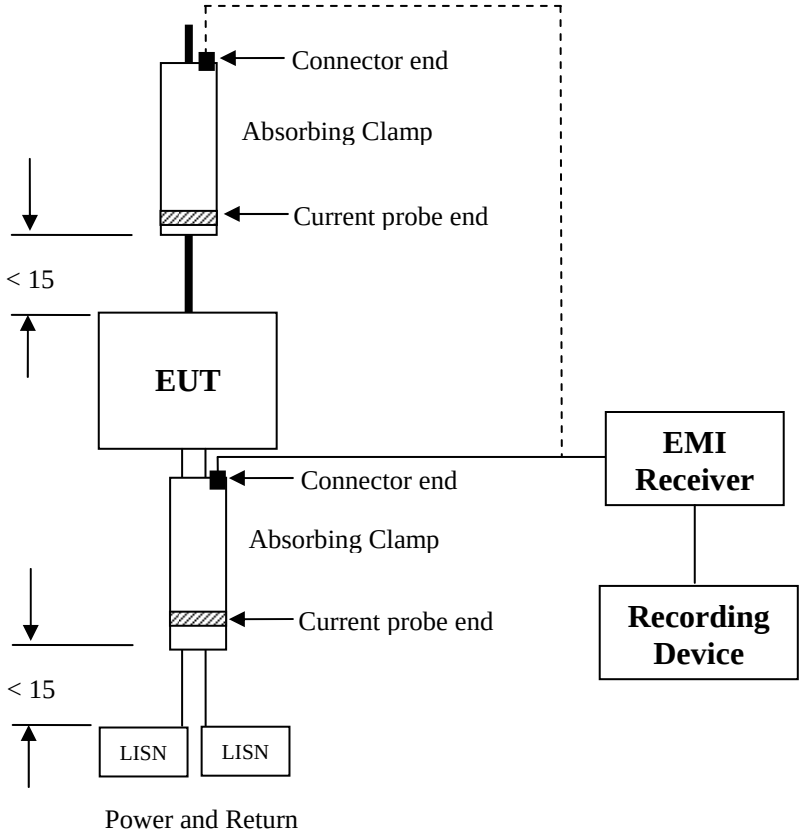

FIGURE RE102-7. BCE test setup.

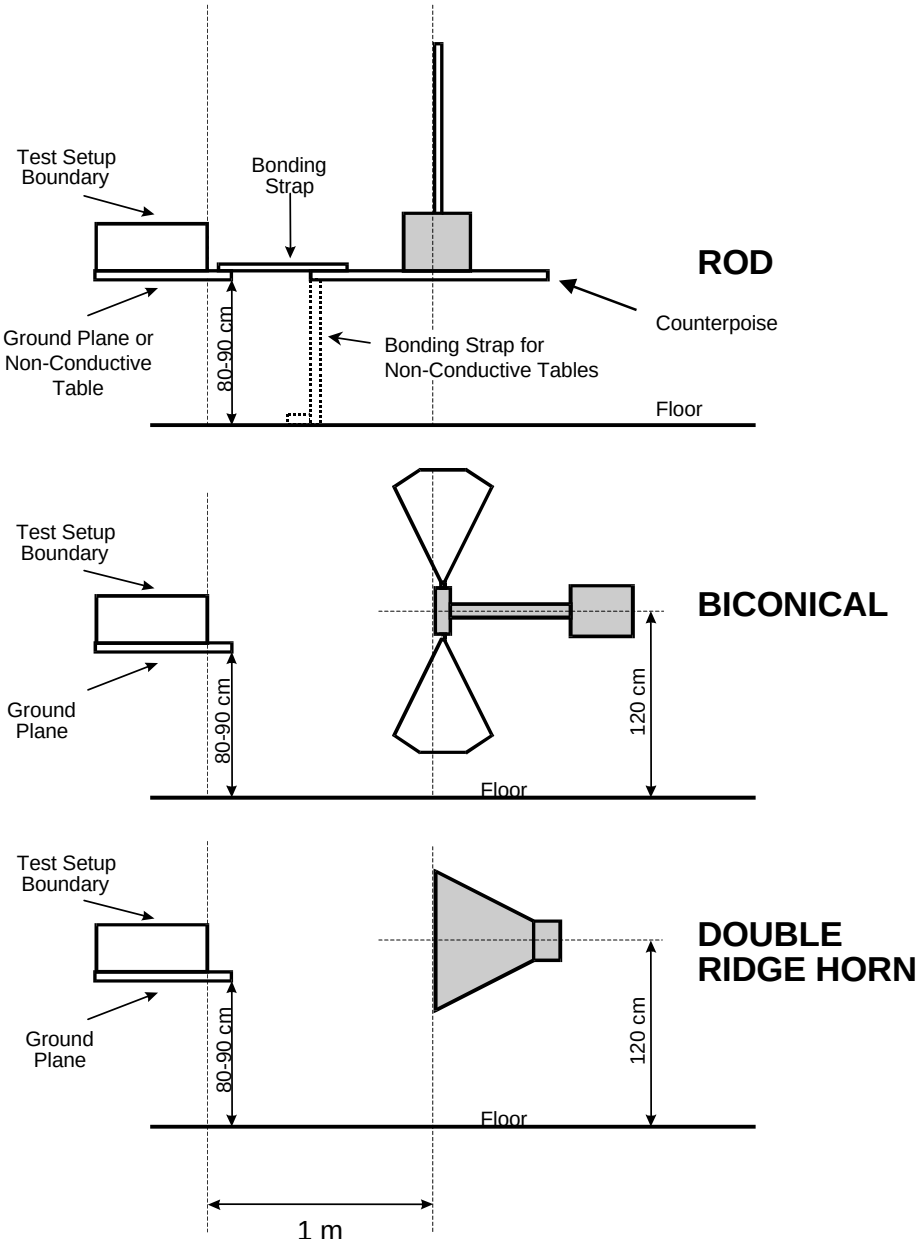

FIGURE RE102-8. Antenna positioning (NOTE: the rod and biconical antenna configurations are not required for SSV testing).

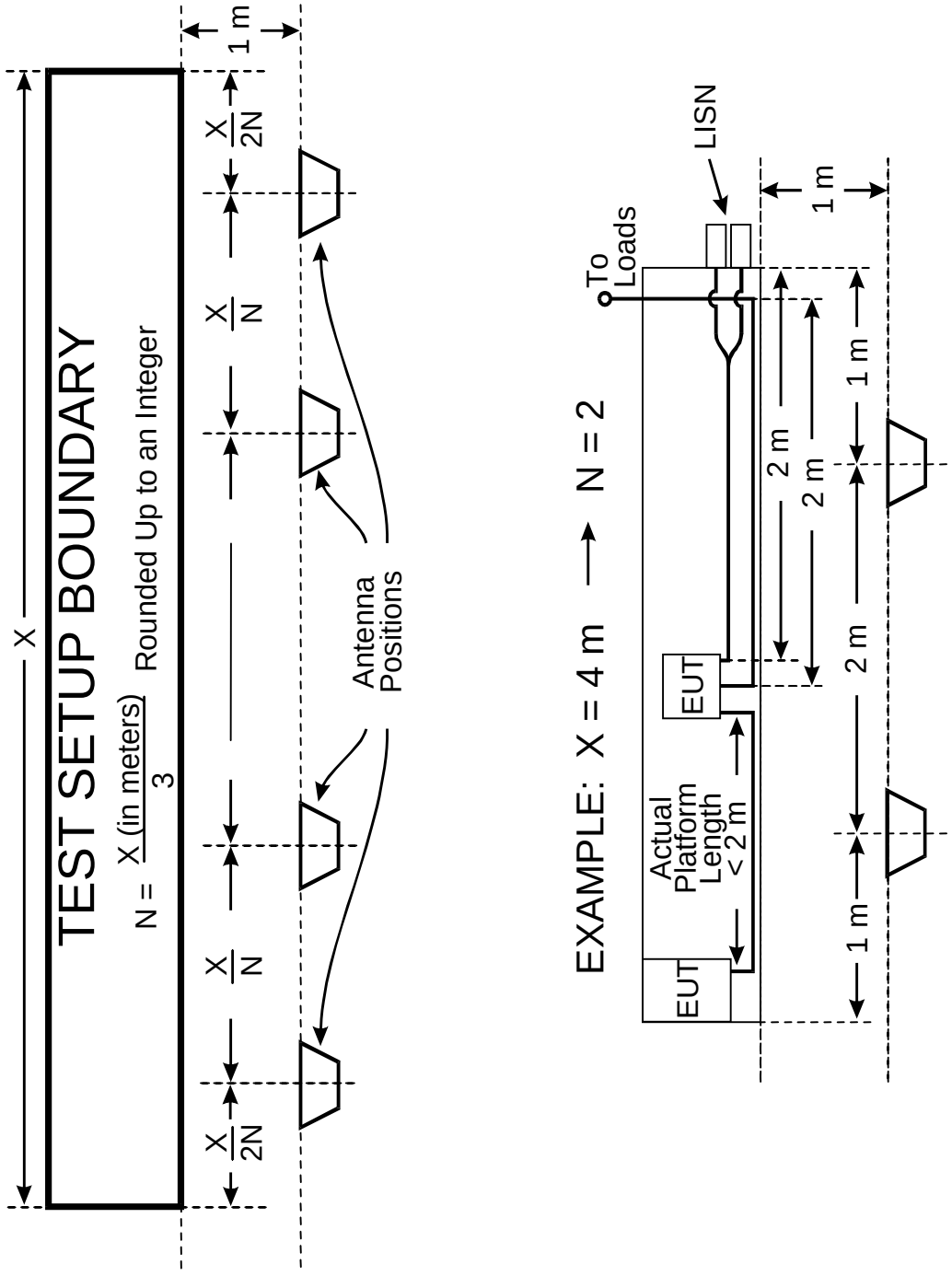

FIGURE RE102-9. Multiple antenna positions.

6.8 RS103, radiated susceptibility, electric field, 30 MHz to 18 GHz.

6.8.1 RS103 applicability.

This requirement is applicable to equipment and subsystem enclosures and all interconnecting cables. The requirement is applicable as follows:

a. 30 MHz to 18 GHz

b. 18 GHz to 40 GHz *optional (required only if specified in the procurement specification

The requirement at the tuned frequency of an antenna-connected receiver is 20 dB above the RE102 limit associated with the particular platform application, with the antenna port dummy loaded and shielded.

6.8.2 RS103 limit.

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to the radiated electric fields listed in Table RS103-1 or Table RS103-2 (as applicable) and modulated as specified below the tables. EMC critical equipment is defined in SL-E-0001, Specification Electromagnetic Compatibility Requirement. The requirement shall be met for both horizontally and vertically polarized fields. Circular polarized fields are not acceptable.

Table RS103-1. RS103 limits for EMC critical equipment (as defined in SL-E-0001).

Frequency	Test Level (V/m) Square Wave Modulation	Test Level (V/m) Low prf Pulse Modulation
30 MHz – 1 GHz	20	N/A
1 – 18 GHz	N/A	200

Table RS103-2. RS103 limits for non-EMC critical equipment.

Frequency	Test Level (V/m) Square Wave Modulation	Test Level (V/m) Low prf Pulse Modulation
30 MHz – 18 GHz	20	N/A

50% duty cycle pulse or amplitude modulation: use 1kHz, 50% duty cycle pulse modulation with at least 40 dB on/off ratio, or square wave amplitude modulation with at least 99% depth.

Low pulse repetition frequency (prf) pulse modulation: use a 4 microsecond pulse at a 1 kHz prf from 1 to 18 GHz.

6.8.3 RS103 test procedures.

6.8.3.1 Purpose.

This test procedure is used to verify the ability of the EUT and associated cabling to withstand electric fields.

6.8.3.2 Test Equipment.

The test equipment will be as follows:

Table RS103-3. METF RS103 Equipment.

Item	METF Equipment	Calibration ID	Calibration Due Date
Signal Generator	HP83620B, HP8341B or Agilent E8257C or equivalent		
Signal Generator (pulse modulation source)	Agilent 33120A or 33220A or equivalent		
Amplifier (14kHz-220MHz)	AR 150A220 or AR 250A250A or equivalent	N/A	N/A
Amplifier (80MHz-1GHz)	AR 100W1000M3 or AR 250W1000A or equivalent	N/A	N/A
Amplifier (1GHz-2.8GHz)	AR 200T1G3A or Logimetrics A610/LS or equivalent	N/A	N/A
Amplifier (2.8GHz-7.5GHz)	AR 200T2G8AM3 or Logimetrics A600/EH or equivalent	N/A	N/A
Amplifier (7.5GHz-18GHz)	AR 250T8G18 or Logimetrics A600/IJ or equivalent	N/A	N/A
Transmit Antenna (30MHz-200MHz)	ETS-Lindgren 3109PX or equivalent	S/N 00040555	N/A
Transmit Antenna (200MHz-1GHz)	EMCO 3106 or equivalent		N/A
Transmit Antenna (1GHz-18GHz)	EMCO 3115 or equivalent		N/A

Item	METF Equipment	Calibration ID	Calibration Due Date
Electric Field Sensor (14kHz-1GHz)	AR FP5000	_____ _____	_____ _____
Electric Field Sensor (80MHz-40GHz)	AR 2080 or ARFP5080 _____ _____	_____ _____	_____ _____
LISN (Positive Lead)	Solar MIL-STD-461E LISN Model # _____		
LISN (Return Lead)	Solar MIL-STD-461E LISN Model # _____		
Test Software		N/A	N/A

6.8.3.3 Setup.

The test setup shall be as follows:

a. Maintain a basic test setup for the EUT as shown and described in Figures 1 through 5 and 5.3.8.

b. For electric field calibration, electric field sensors are required from 30 MHz to 1 GHz. Field sensors are also used above 1 GHz for METF RS103 testing.

c. Configure test equipment as shown in Figure RS103-1.

d. Calibration. Placement of electric field sensors (see 6.8.3.3b). Position sensors 1 meter from, and directly opposite, the transmit antenna as shown in Figures RS103-2 and RS103-3 and a minimum of 30 cm above the ground plane. Do not place sensors directly at corners or edges of EUT components.

e. EUT testing.

(1) Placement of transmit antennas. Antennas shall be placed 1 meter from the test setup boundary as follows:

(a) 30 MHz to 200 MHz

1 Test setup boundaries ≤ 3 meters. Center the antenna between the edges of the test setup boundary. The boundary includes all enclosures of the EUT and the 2 meters of exposed interconnecting and power leads required in 5.3.8.6. Interconnecting leads shorter than 2 meters are acceptable when they represent the actual platform installation.

2 Test setup boundaries > 3 meters. Use multiple antenna positions (N) at spacings as shown in Figure RS103-3. The number of antenna positions (N) shall be determined by dividing the edge-to-edge boundary distance (in meters) by 3 and rounding up to an integer.

(b) 200 MHz and above. Multiple antenna positions may be required as shown in Figure RS103-2. Determine the number of antenna positions (N) as follows:

1 For testing from 200 MHz up to 1 GHz, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

2 For testing at 1 GHz and above, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

(2) Maintain the placement of electric field sensors as specified in 6.8.3.3d(1) above.

6.8.3.4. Procedures.

The test procedures shall be as follows:

a. Turn on the measurement equipment and EUT and allow a sufficient time for stabilization.

b. Assess the test area for potential RF hazards and take necessary precautionary steps to assure safety of test personnel.

c. Calibration. Electric field sensor procedure. Record the amplitude shown on the electric field sensor display unit due to EUT ambient. Reposition the sensor, as necessary, until this level is < 10% of the applicable field strength to be used for testing.

d. EUT Testing.

(1) E-Field sensor procedure.

(a) Set the signal source to the applicable modulation as noted in Tables RS103-1 or RS103-2 and using appropriate amplifier and transmit antenna, establish an electric field at the test start frequency. Gradually increase the electric field level until it reaches the applicable limit.

(b) Scan the required frequency ranges in accordance with the rates and durations specified in Table VI. Maintain field strength levels in accordance with the applicable limit. Monitor EUT performance for susceptibility effects.

(2) If susceptibility is noted, determine the threshold level in accordance with 5.3.10.4.3 and verify that it is above the limit.

(3) Perform testing over the required frequency range with the transmit antenna vertically polarized. Repeat the testing with the transmit antenna horizontally polarized.

(4) Repeat 6.8.3.4d for each transmit antenna position required by 6.8.3.3e.

6.8.3.5 Data Presentation.

Data presentation shall be as follows:

a. Provide graphical or tabular data showing frequency ranges and field strength levels tested.

b. Provide the correction factors necessary to adjust sensor output readings for equivalent peak detection of modulated waveforms.

c. Provide graphs or tables listing any susceptibility thresholds that were determined along with their associated frequencies. Record the test results in the test run log spreadsheet on the METF computer workstation.

d. Provide diagrams or photographs showing actual equipment setup and the associated dimensions.

e. Complete Table RS103-4 to document the METF equipment configuration used for each RS103 frequency range.

Table RS103-4. METF RS103 test equipment configuration.

Frequency Range (Hz)	Signal Generator	Modulation Source	Frequency step size	Target E-field (V/m)	Antenna	Amplifier	Field probe(s)
			0._____f_o				
			0._____f_o				
			0._____f_o				
			0._____f_o				
			0._____f_o				
			0._____f_o				
			0._____f_o				
			0._____f_o				
			0._____f_o				
			0._____f_o				
			0._____f_o				

6.8.3.6 RS103 Test Procedure/Configuration Notes

EUT:_____

6.8.3.7 RS103 Test Procedure Deviations

EUT:_____

The MFOP-FA-EMI-304 RS103 facility operating procedures were followed during the RS103 test with the exception of the following deviations:

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METF Test Conductor signature: _____ Date: _____

EUT Test Conductor signature: _____Date: _____

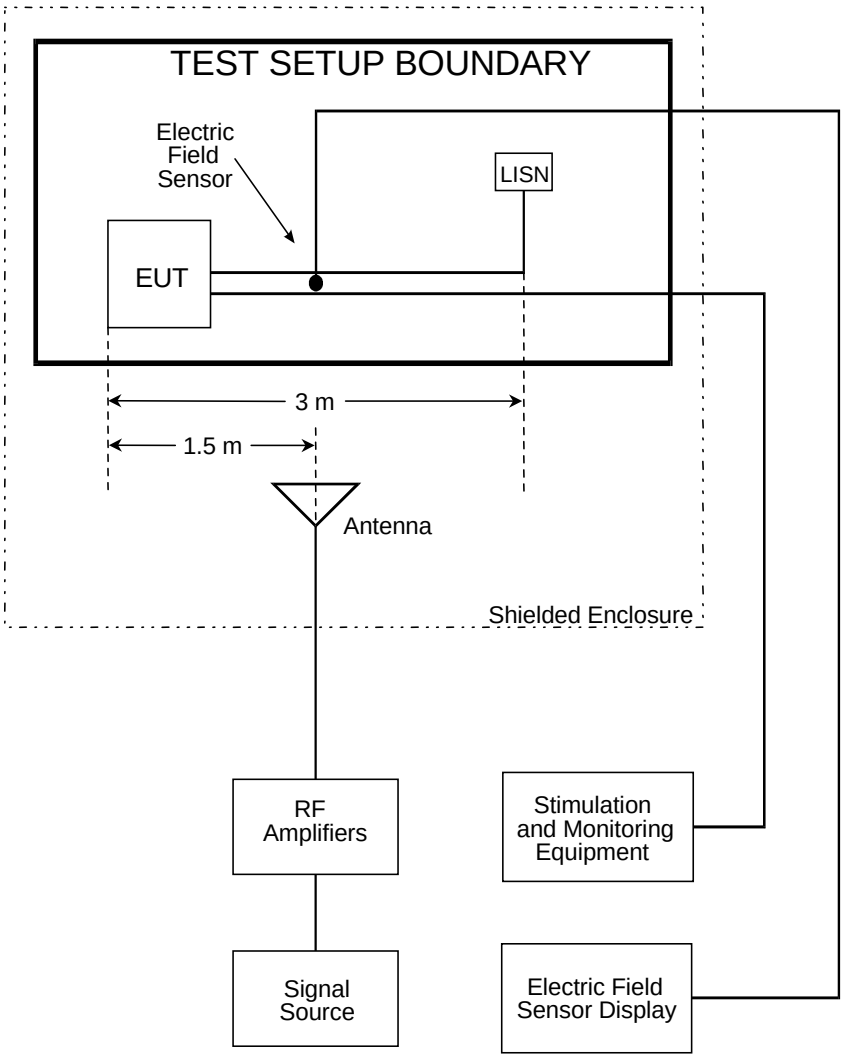

FIGURE RS103-1. Test equipment configuration.

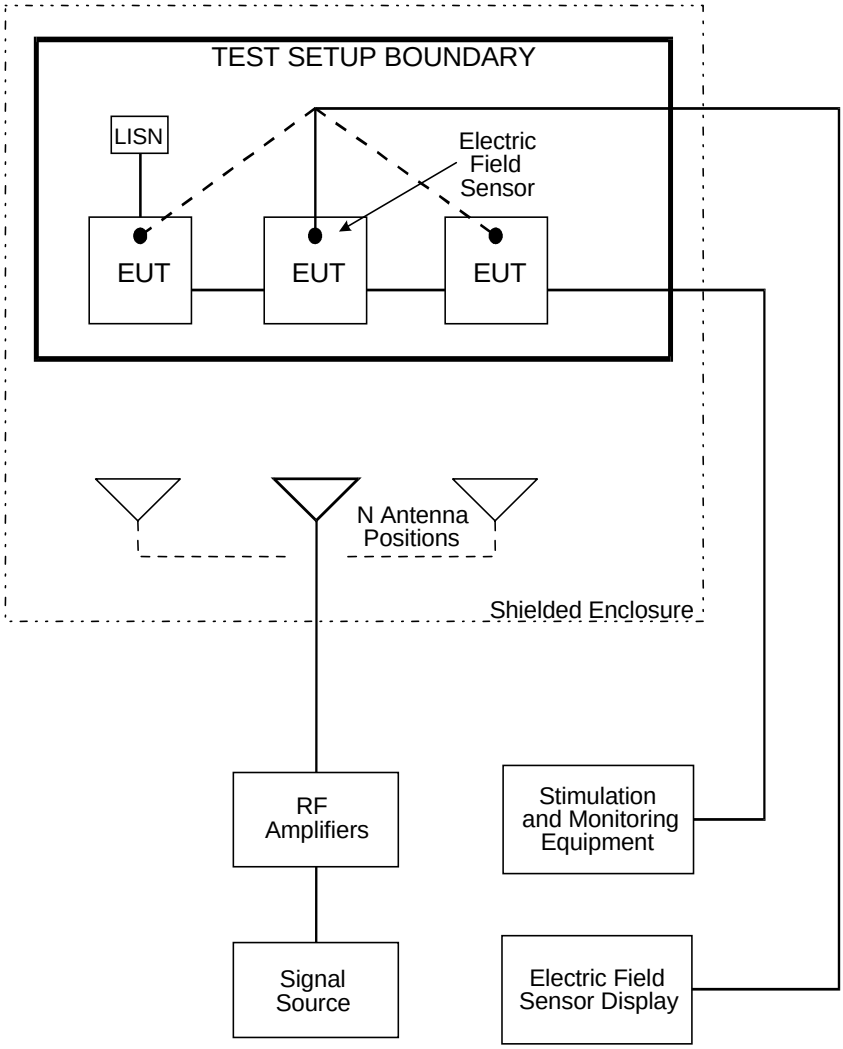

FIGURE RS103-2. Multiple test antenna locations for frequency > 200 MHz.

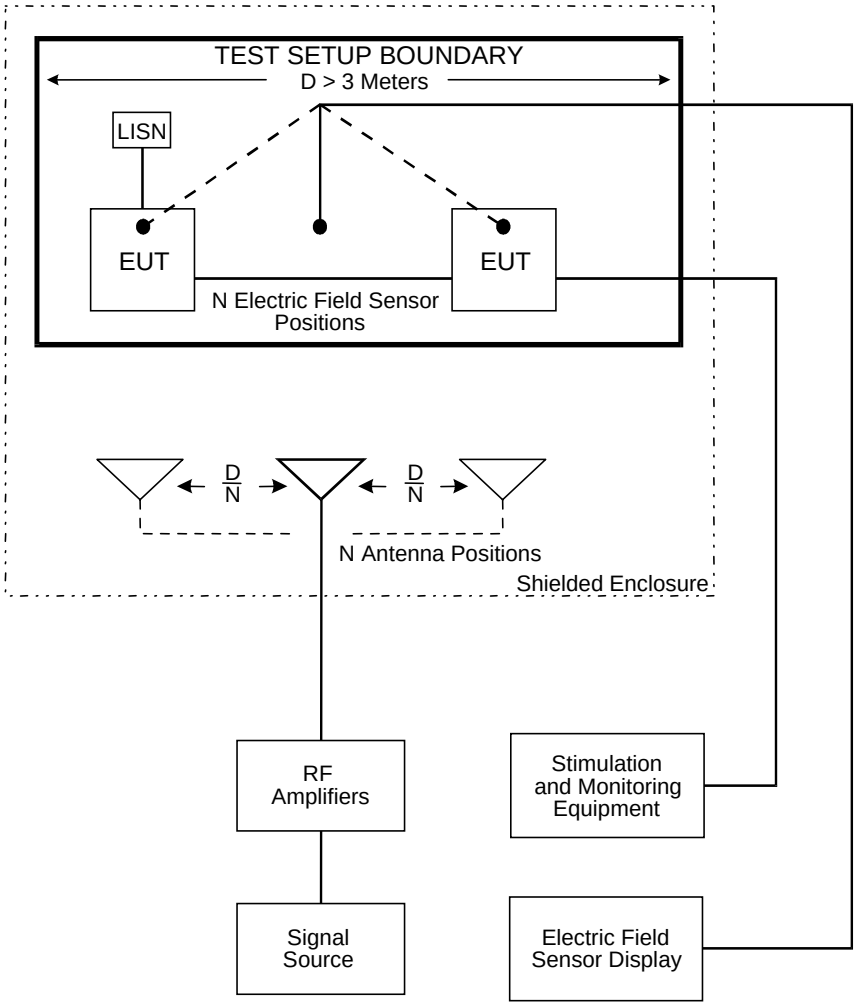

FIGURE RS103-3. Multiple test antenna locations for N positions, D > 3 meters.

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